NATIONAL ACTIVITIES

CHAPTER 7

AUSTRALIA

7.1 GOVERNMENT PROGRAMS

7.1.1 Policy

The Australian government produced a paper titled *The Development and Use of Renewable Energy Technologies* in 1996 as part of the development of a National Sustainable Energy Policy. The paper reported on the opportunities and the constraints in the development and use of renewable energy technologies including wind power. The paper also provided advice to the government on the development and implementation of a Renewable Energy Industry Program.

The key recommendations of the paper include a declaration that:

1. The renewable energy industry is strategic for Australia and requires development assistance. (Strategic because of the potential environmental benefits, contribution to economic growth and, in the long term, enhancement of energy security),
2. A peak renewable energy industry body be formed,
3. Australia establish explicit goals for increasing the contribution of renewable energy sources,
4. Accelerated tax concessions be increased for renewable energy R&D and
5. Increased funding be provided to support R&D.

In late 1996, the Commonwealth Government released a paper titled *Sustainable Energy Policy for Australia* to stimulate public consideration of a sustainable energy policy for Australia. The government's aim is to provide an energy policy framework that integrates economic, environmental and social goals. A sustainable energy policy is not expected to be completed until after the Commonwealth Government elections.

7.1.2 Strategy

The current strategy for the development of renewables includes:

Support of research and development and demonstration of renewable energy technologies,
Industry and government cooperation on reducing greenhouse gas emissions.

The Energy Research and Development Corporation (ERDC) was created in 1990 by the Commonwealth Government. It defined its role as stimulating and facilitating investment in effective energy research. Its objectives were broadly in the energy industry and included the

Figure 7.1 Kooragang Island wind turbine.

need to increase the diversity of supply covering gas, liquid fuels and renewable energy. It achieved this by investing as industry partners in energy research, development and demonstration projects and developing links with the energy industry, companies and researchers. It also has the roles in Australia as the signatory to the IEA Wind Implementing Agreement and as a member of the consortium of interested parties that currently represent the industry in Australia.

In 1996, the Australian Co-operative Research Centre on Renewable Energy (ACRE) was established to facilitate the development and commercialization of renewable energy technology through co-operative arrangements between universities, government organizations and industry. ACRE currently has eight programs. The programs that address the application of wind power cover Power Generation, Power Conditioners, System Integration and Demonstration projects.

The Greenhouse Challenge was established in 1995 and is an initiative whereby industry and government enter into co-operative agreements to reduce greenhouse gas emissions through voluntary industry action. While some wind farm developments are encouraged by the program, the focus is on improving industry energy and process efficiency, and other means of reducing emissions or increasing sinks.

The Electricity Supply Association (ESAA) which is the national peak body representing the interests of the electricity supply industry is assisting in the application of the strategies through its facilitation of co-operative research endeavors among Australian electricity businesses and its increased involvement with the International Energy Agency Implementing Agreements.

7.1.3 Targets and Market Stimulation

The application of wind turbine technology is being stimulated by various government instruments and external factors. The stimuli are generally positive although some re-focusing occurred in 1997.

The Sustainable Energy Development Authority (SEDA) commenced operation in August 1996 with a mission to reduce the level of greenhouse gas emissions in New South Wales (NSW) by investing in the commercialization and use of sustainable energy technologies. As a NSW Government agency, its activities are broad and include:

Intervention where market failures are hindering the economically efficient utilization and Application of sustainable energy technologies;
Supporting technologies which are on a development and demonstration path leading to commercialization, but it will not support fundamental research.

SEDA’s renewable energy program has contributed to the demand for renewable energy by promoting Green Power in the NSW electricity market. SEDA has also assisted in the early stages of the assessment of wind power projects including the assessment of the wind resource. A number of wind turbine installation developments have already been encouraged in NSW by the demand for Green Power including the demonstration wind turbine at Kooragang Island and a wind farm at Crookwell. More wind farms are planned to meet the demand for Green Power.

In November 1997, as part of Australia’s response to addressing its contribution to climate change and reduction of greenhouse gas emissions, the Commonwealth Government announced that mandatory targets are to be set for electricity retailers to source an additional 2% of their electricity from renewable energy sources by

2010. A specific target for wind power capacity is yet to be established. The mechanisms for applying the targets are expected to established between the Commonwealth and the States in 1998.

In the same announcement on climate change and reduction of greenhouse gas emissions, AU$60 million in funding was also promised by the Commonwealth Government for investment and commercialization of renewable energy technologies and the demonstration of a few leading edge "showcase" projects. It is not known what proportion will be allocated to wind energy related projects. The funds will be administered by a Commonwealth Greenhouse Office planned to be established in 1998.

In 1997, the Commonwealth Government budget reduced the accelerated tax concession rate for eligible R&D expenditure. Also, Australia's peak energy R&D funding body, Energy Research and Development Corporation (ERDC), had its funding withdrawn with closure planned for 1998.

While the tax concession reduction and loss of ERDC have produced a less favorable environment for R&D, the re-focusing of funding support for renewables through ACRE and other programs, the advent of Green Power schemes and the establishment of a mandatory target for renewables, if applied successfully, have the potential to rapidly stimulate the development of wind farms in Australia.

7.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

7.2.1 Installed Wind Turbine Capacity

The main source for increased wind power capacity in Australia for 1997 has been in wind-diesel power systems, as demonstration machines and also as a source of green electricity. Approximately 0.45 MW of remote wind-diesel and 0.6 MW for grid connected demonstration machines has been added bringing Australia's total capacity to about 3.9 MW at the end of 1997. See Table 7.1 for further details.

7.2.2 Installed Conventional Capacity

Australia's installed capacity as of June 1996 was just over 40,000 MW. Over a third of the capacity is installed in New South Wales. The plants produced 153,000 GWh of electricity in 1995/96 mainly from coal fired thermal stations (80%) and renewable hydro (19%). Other renewables contribute less than about 1%. The growth in electricity consumption was 3.8% in the last decade but has slowed down since 1990 as a result of a slow down in economic activity.

7.2.3 Numbers/Type, Make of Turbines/Ownership

In 1997 two turbines were installed by state government-owned electricity utilities on Thursday Island by the Far North Queensland Electricity Board and one turbine was installed on Kooragang Island by EnergyAustralia. All these machines were supplied by Vestas.

The installation of the two 225 kW machines on Thursday Island was completed in July 1997. The turbines form part of an off grid wind diesel power system and will provide about 10% of the annual communities electricity needs and reduce diesel fuel consumption by 360,000 litres or AU$250,000 per year.

The 600-kW wind turbine on Kooragang Island was opened in November 1997 and is providing an estimated 1GWh pa of green power into the state electricity grid. The turbine is currently the largest in Australia.

A number of wind farms were also in various stages of development at the end of 1997.

Pacific Power, one of the three power generators in NSW, is constructing a 5-MW farm at Crookwell in a joint venture with Great Southern Energy using 600-kW Vestas turbines. Commissioning is planned for 1998. The Crookwell wind farm is going to be the largest wind farm in Australia when commissioned and the first wind farm connected to a centralized electricity grid.

In Victoria, a publicly listed company, Energy Equity Corporation, has lodged planning permits for three sites near Portland with plans to construct a 20-MW farm at one of the sites. Power purchase agreements are being completed with electricity retailers. Completion of the farm is planned for 1999.

Western Power Corporation is to install a 230-kW Enercon turbine at Denham, Western Australia, as part of wind diesel power system. Completion is expected in 1998.

In Tasmania, a 0.75-MW farm is being constructed at Huxley Hill on King Island with power planned to be feeding from the Nordex 250-kW turbines into a diesel-powered system in 1998.

In the Northern Territory, an 80-kW wind turbine is planned to be installed in a remote Aboriginal community hybrid power system.

7.2.4 Plant Types and Form of Ownership

Wind turbines installed in Australia are owned either by government-owned utilities, (including electricity retailing and generation businesses), private companies or individuals. Some wind farms are being jointly developed by a government-owned generation businesses in partnership with electricity retailers. All wind turbine installations are small to medium with less than 10 machines and often consist of individual machines.

7.2.5 Performance

An estimated 7.5 GWh of energy was produced by wind generation in 1997 and is the same as that produced in 1996. The lower than expected energy production, despite the increase in installed capacity, was due predominantly to below average wind conditions experienced at the Ten Mile Lagoon wind farm.

7.2.6 Operational Experience

Limited wind turbine operational data is available for Australia installations in 1997. Estimates of the energy generated is shown in Table 7.1.

7.3 MANUFACTURING INDUSTRY

There is one manufacturer of small size machines (Westwind) and a number of

Table 7.1 Wind Turbine Installations in Australia at end of 1997

LOCATION	MANUFACTURER	NO. kW	TOTAL MW
Malabar	WindMaster	1 x 150	0.150
Breamlea	Westwind	1 x 60	0.060
Flinders Is.		1 x 55	0.080
		1 x 25	
Salmon Farm	Westwind	6 x 60	0.360
Cooper Pedy	Nordex	1 x 150	0.150
Ten Mile Lagoon	Vestas	9 x 225	2.025
Kooragang	Vestas	1 x 600	0.600
Thursday Is.	Vestas	2 x 225	0.450
*estimated		TOTAL	3.875

low volume manufacturers of small size machines and turbine components.

The current market volume for medium to large grid connected wind turbines in Australia is too small to maintain the viability of a local manufacturing facility.

7.4 ECONOMICS

7.4.1 Electricity Prices

The electricity supply industry is undergoing major reforms to structure, operation and ownership. The reforms center on transforming the electricity utilities from vertically integrated to a horizontally integrated form, from government owned to privately owned, and breaking up monopolies and opening up the electricity market to competition. Progress over the last few years has reached the stage where the National Electricity Market Phase 1 (NEM1) commenced operations in May 1997. Full National Electricity Market reform, with all major eastern states participating, is expected in 1998.

Before NEM, electricity prices varied state by state. Currently, generators from Victoria and New South Wales are bidding on the spot market to supply electricity and wholesale purchasers (retailers and large customers) buy electricity at the spot price set every half an hour. The introduction of the NEM has established a common price for electricity for the participating eastern states. The daily weighted average spot price for electricity generation on the spot market has varied typically from about AU$0.008 / kWh to AU$0.01 / kWh and although there is uncertainty about the level of spot prices once Queensland and South Australia join the market, it is expected to remain at these levels while a surplus of thermal generation capacity exists in the electricity market.

Wind energy does not enjoy any subsidies in Australia and so is unable to compete in the spot market, even at the best sites, with the current low price of thermal and hydro generation.

7.4.2 Invested Capital

The capital investment in commissioned wind farms and individual machines plus associated infrastructure is estimated at AU$14 million in December 1997 dollars.

7.4.3 Turbine / Project Costs

The cost of wind turbines in Australia are higher than elsewhere in the world due to the cost of freight from manufacturing facilities in Europe or the United States to

COMMISSIONING DATE	OWNERSHIP	APPLICATION	1997 GWh*
1986	Government Utility	Grid Connected	
1987	Private Individual	Grid Connected	0.160
1988	Private Company	Wind Diesel	0.180
1996	Private Company		0.040
1989	Government Utility	Wind Diesel	0.800
1991	Government Utility	Wind Diesel	0.275
1993	Government Utility	Wind Diesel	5.700
1997	Government Utility	Grid Connected	0.100
1997	Government Utility	Wind Diesel	0.600
		TOTAL	7.475

Australia. Estimated costs including towers and excluding foundations is currently about AU$1300 / kW to AU$1500 / kW installed.

Wind farm projects are currently costing from AU$5000 / kW installed for small wind-diesel applications to about AU$2000 / kW for small wind farms connected to the grid. This cost is expected to drop towards AU$1500 / kW for larger wind farms.

7.5 MARKET DEVELOPMENT

7.5.1 Market Stimulation Instruments

The industry currently does not enjoy any market stimulation from subsidies. For complying R&D projects, accelerated tax concessions are available.

7.5.2 Planning and Grid Issues

The low level of wind energy development to date has not been significantly constrained by the grid connection cost, integration into the local grid or planning issues. However the low electricity price and the lack of unit energy based incentives or CO_2 taxes and uncertain wind energy capacity targets have not been very encouraging for developers of commercial wind farms.

Wind turbine installations have typically taken place to date at sites relatively close to transmission lines. Current low levels of wind power development in the local feeders of centralized electricity grids have not caused concern regarding integration of wind turbines into either the grid or power system.

Most development has occurred as part of either wind diesel applications where wind power replaces expensive diesel power or, for sale as green power by electricity retailers to customers willing to pay a premium for clean renewable electricity. The take up for such green power schemes by customers has been typically one or two percent and is growing slowly.

7.5.3 Institutional Factors

Funding subsidies and promotion of Green Power provided by the NSW Sustainable Energy Development Authority and more recently, the Climate Change initiatives, are emerging as the most likely mechanisms for encouraging increased rates of development over the next few years. Uncertainty in the introduction of the initiatives though, and the reluctance by government to embrace higher priced renewable energy sources due to possible social and economic impacts, may dampen the rate of wind power developments.

7.5.4 Impact of Wind Turbines on the Environment

Wind farm developments are new to Australia, have been typically developed in remote areas and are of small scale. They have so far attracted little opposition in the planning and government approvals processes although this may change as the scale of developments increases and farms are developed closer to provincial townships.

7.5.5 Financing

Hurdle rates for assessing the economic viability of government-owned utility projects is currently about 6% to 8%.

7.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

7.6.1 Funding Levels

The budget for the Commonwealth Government funded Australian Co-operative Research Centre on Renewable Energy (ACRE) totals AU$40 million spread over seven years (commencing July 1996) for all its programs of which about 10% is allocated to programs which directly benefit the development of wind energy. A funding contribution of over AU$10 million comes from the Commonwealth Government, AU$5 from ERDC and the remainder from matched contributions from private sector industries and utilities. Electricity utilities are also anticipated to provide up to AU$30 million for the funding of the development of generation capacity and associated infrastructure.

The NSW Government is committed to fund the first three years of the Sustainable Energy Development Authority's operation, at a total budget of $39 million over three years commencing mid-1996. The contribution over that period to the Renewable Energy program is AU$10 to 13 million for Commercialization of Technology, Transformation of the Market, for Industry Assistance Information, and Education and Training. An identifiable funding allocation within that program for wind energy has not been made.

7.6.2 Priorities

The principal objective for current R&D renewable energy programs by ACRE is to undertake strategic research in generation, storage, power conditioning, energy efficiency and systems integration. Effective demonstration of the technology is also seen as important in the lead up to the development of a Renewable Energy Policy for Australia.

For wind power, the current priorities of ACRE are to develop a viable small wind turbine or component manufacturing capability and to improve the performance of wind diesel power or hybrid power systems for which there is a large market in our region of the world.

7.6.3 New Concepts

ACRE in conjunction with Westwind and several universities currently, has a research program in place for the development of 5-kW to 60-kW turbines which incorporate variable voltage, super magnets, and direct drive (no gearbox) with power electronics. The generator design originates in high efficiency motors designed for solar cars. A 5-kW version has been commissioned, a 10-kW prototype is under construction and a 25-kW version is planned.

Government owned electricity utilities and retailers in most States are also conducting demonstration projects of varying scale, partially at least to gain experience in the 'new' wind technology, to produce green power for sale to customers and to demonstrate their commitment to the environment. They are being assisted in some cases by Universities and industry associations.

An 80-kW Lagerwey turbine is planned to be installed at Eppenarra in the Northern Territory in a joint R&D program between ACRE and the Power and Water Authority. The turbine will be part of a remote Aboriginal community's diesel / wind / PV / Battery / Inverter hybrid power system that aims to reduce current fuel consumption by 50%. Demand side management may improve performance further.

At Denham, a 230-kW Enercon variable speed machine is to be the subject of a R&D program aimed at improving the power conditioning of the combined turbine and its control system in a wind diesel power system. The program industry sponsor, Western Power Corporation, is performing the R&D in conjunction with ACRE and other members of ACRE. Wind penetrations of 60% to 80% are hoped to be achieved while using the existing conventional diesel generators.

An R&D program is being conducted by the Hydro Electric Corporation on the wind diesel power system being developed on King Island. The system, using three 250-kW Nordex turbines, will demonstrate the use conventional generation technology with advanced control systems in a region noted for high average wind speeds. The stall regulated machines with fast switching resistor banks will be the subject of a research program aimed at verifying the methodology adopted for assessing the project feasibility, identifying limitations to maximizing fuel savings and achieving optimum fuel savings while maintaining the power system quality and reliability.

EnergyAustralia has developed in association with industry, a 5-kW wind turbine suitable for remote area power supply applications and is assisting the University of Newcastle in the application of their high-efficiency blade for a small turbines.

Monash University has recently commenced the compilation of an Australasian wind atlas using the data available from existing and past State wind monitoring programs. It is planned for release in 1998/99 as part of an ANZSES (Australia New Zealand Solar Energy Society) sponsored Australasian wind energy handbook.

7.6.4 MW rated Turbines

The wind turbine manufacturing industry is relatively small in Australia. The R&D effort is concentrated mainly on the development of small wind turbines suitable for remote community power supplies. R&D is currently neither being conducted nor proposed for wind turbine technology with an installed capacity greater than 60 kW.

7.6.5 Offshore Developments

Development of large wind farms is only in its infancy in Australia and there are extensive undeveloped areas in coastal regions with good wind resource and reasonable proximity to transmission lines. Therefore there is little interest currently in the development of offshore wind farms.

CHAPTER 8

CANADA

8.1 GOVERNMENT PROGRAMS

8.1.1 Aims and Objectives

The focus of the Canadian National Program continues to be on R&D to develop safe, reliable and economic wind turbine technology to support field trials and to exploit Canada's large wind potential.

8.1.2 Strategy

The main elements of the Wind Energy R&D program are: Technology Development, Resource Assessment, Test Facilities, and Information / Technology Transfer. Field trial projects are selected to evaluate the performance of the equipment under special environmental conditions or for specific applications.

8.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

8.2.1 Installed Wind Capacity

1. Canadian Niagara Power Co.18.9 MW
   9 MW - Keneteck 350 kW turbines in operation since January 1, 1994
   9.9 MW - Keneteck 350 kW turbines in operation since September 1, 1994
2. CWT Power 1.2 MW
   100 and 150 kW Adecon Vertical Axis Wind Turbines
3. Vision Quest Windelectric1.2 MW
   600 kW Vestas turbines
4. Hydro-Quebec 2.25 MW
   750 kW NEG-Micon turbines
5. Various other installations with a total capacity of 2.2 MW.

Total installed capacity at the end of 1997 of 25.75 MW.

8.2.2 Installed Conventional Capacity

The total installed conventional capacity in Canada at the end of 1996 (the most recent year for which statistics are available) was 116,939 MW, which includes coal, oil, natural gas, nuclear and hydropower plants.

8.2.3 Types of Turbines

1. Andecon, 100-kW and 150-kW VAWT turbines with external support frame constant speed, stall controlled.
2. Keneteck, 33 M-V5, 350-kW turbines with variable speed, variable pitch blades and lattice tower.
3. NEG-Micon, 750-kW turbines;
4. Vestas, 600-kW Vestas turbines, and;
5. Tacke, 600-kW turbines.

8.2.4 Performance

The total wind energy production in 1997 was 64 GWh.

8.2.5 Operational Experience

The operating data for the two main wind farms, privately owned and operated, (CWT Power and Canadian Niagara Power), is limited to energy output figures.

An 80-kW Lagerwey turbine was installed at Cambridge Bay, NWT in October 1994. The turbine is performing very well. The oil in the yaw mechanism became thick during very cold weather in January 1995. This slowed the rate of yaw considerably. The oil was changed to a grade more suitable for cold weather and it cured the problem. This led to two additional Lagerway turbines being installed at Coppermine in the Northwest Territories.

Huron Windpower Inc. (HWI), formerly Tacke Windpower of Huron Park, Ontario, as per an agreement with NRCan, has installed a 600 kW turbine near Kincardine, Ontario. The turbine, modified for cold weather conditions, went through one year of evaluation and has been performing trouble free. It was producing more power than the generator rating due to higher wind density. This was fixed by changing the blade pitch. HWI has manufactured and exported blades for the Tacke 600 and for other wind turbines.

The150-kW Bonus turbine installed on the Haeckel Hill (1450 m height) near Whitehorse in Yukon was commissioned in August 1993. The turbine's energy output in 1996 was 453,875 kWh.

The turbine is located on the west side of White Horse and near a major migrating corridor used by many thousands of large waterfowl and other birds (passerines and birds of prey). On the east side of White Horse, also close to this corridor, there are some microwave communication antennae and radio transmission towers on top of the Grey Mountain ridge. Both of these locations were thought to be likely sites for bird strikes since the elevations for these two mountains are similar. These two mountains are about 20 km apart. Observations of bird flights were carried out during the spring (mid-April to mid-May) and fall (September to October) migrating periods. Bird monitoring continued for five years and no dead birds were detected.

8.3 MANUFACTURING INDUSTRY

8.3.1 Status / Number / Sales of Manufacturers

1. Dutch Industries (water pumps), Regina, Saskatchewan;
2. Koenders, (water pumpers and aerators) Englefield, Saskatchewan;
3. CWT 150-kW is the only turbine designed and manufactured in Canada by CWT Power Ltd. of Calgary;
4. Huron Winpower Inc, Huron Park, Ontario is manufacturing blades for Tacke 600-kW, for Zond 750-kW and Wenvor-Vergnet 25-kW wind turbines;
5. Some components for the Atlantic Orient 50-kW and for Lagerway 80-kW are also manufactured in Canada.

8.3.2 Support Industries

Control system, inverter, tower manufacturers operate in Canada.

8.4 ECONOMICS

8.4.1 Electricity Prices

Electricity prices varied depending on the province and sometimes even within the same province. The price range, in January 1997 was:

1. For residential customers: from CAD 0.067 / kWh to CAD 0.151 / kWh;
2. For commercial customers: from CAD 0.067 / kWh to CAD 0.134 / kWh (based on 100 kW billing demand);
3. For industrial customers: from CAD 0.048 / kWh to CAD 0.084 / kWh (based on 1,000 kW billing demand)

8.4.2 Invested Capital

The budget for the Wind Energy R&D (WERD) program of Natural Resources Canada is about CAD 650,000 with contribution of about CAD 1.5 million from contractors, research institutions, and provinces.

8.5 MARKET DEVELOPMENT

8.5.1 Market Stimulation Instruments

Currently, Class 43.1 of the federal Income Tax Act provides an accelerated capital cost allowance (30% capital cost allowance rate computed on a declining balance basis) for certain types of renewable energies—equipment used to generate electricity or to produce thermal energy for direct use in an industrial process.

In addition, the government has legislated the extension of the use of flow-through share financing currently available for non-renewable energy and mining projects to include intangible expenses in certain renewable projects, by creating a new Canadian Renewable and Conservation Expense (CRCE) category in the income tax system. Through CRCE, the Income Tax Act also allows the first, exploratory wind turbine of a wind farm to be fully deducted in the year of its installation, in a manner similar to the one in which the first, exploratory well of a new oil field is being written off.

Natural Resources Canada and Environment Canada have jointly established a Green Power Purchase program which allows developers of wind turbine and other renewable energy sites to sell power through power utility lines, to facilities owned by these two federal government departments, at premiums negotiated through a competitive process.

8.5.2 Constraints

The main constraints for the wind energy development in Canada are the surplus of installed capacity and low cost of conventional energy.

8.5.3 Environmental Impact

There have been no bird kills reported from Haeckel Hill installation or from the five wind turbines at the Atlantic Wind Test Site in PEI.

8.5.4 Financial Aspects

The only financial support for Renewable Energies in Canada are: Class 43 of the Income Tax Act which allows capital write-off at 30% per year on the remaining balance; CRCE which allows the first, exploratory wind turbine of a wind farm to be fully deducted in the year of its installation; and the Green Power Procurement program.

8.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

Development of the High-Penetration-No-Storage Wind / Diesel (HPNSWD) system by Hydro-Quebec and the Atlantic Wind Test Site (AWTS) has been completed. Hydro-Quebec is now evaluating the implementation of a full scale system in a remote community.

The Lagerwey 80-kW wind turbine is undergoing testing at AWTS and is being fitted with a control system and an inverter. The Northwest Territories Power Corporation has installed two additional units at Coppermine, NWT.

The program also supports two test sites:

1. Atlantic Wind Test Site (AWTS) at North Cape, PEI for testing electricity generating wind turbines and wind / diesel systems;
2. Alberta Renewable Energy Test Site (ARETS) at Pincher Creek, Alberta for testing Wind and PV water pumping systems.

Canadian industry has collaborated with Lagerwey of the Netherlands, Atlantic Orient Corp of Vermont, USA., and Vergnet of France.

CHAPTER 9

9.1 GOVERNMENT PROGRAMS

9.1.1 Aims and Objectives

Denmark has a long tradition of implementing vigorous energy policies with broad political support and the keen commitment of a wide range of actors: energy companies, industry, grass roots organizations, municipalities, research institutions, and consumers.

The aim of the first energy strategy, the *Danish Energy Policy 1976*, was to secure Denmark against crises in supply, such as the energy crisis of 1973-74. The following plan, *Energy 81*, could build further, given the drastic price rises of energy after the crisis in 1979-80; it also emphasized socio-economic and environmental considerations. After a period of building up large projects for facilities and markets for natural gas and heat and power generation, the action plan, *Energy 2000*, followed in 1990, introducing the goal of sustainable development of the energy sector. Denmark's Energy Futures, a discussion paper published in December 1995, contains a technical analysis of future scenarios for energy consumption and supply in Denmark. It has been followed and extended by *Energy 21*, the fourth of the energy strategies, which lays down the energy-policy agenda for the years to come.

Development and implementation of wind energy have been included in all energy strategies. Both demand pull policy instruments (financial and other incentives) and technology push policy instruments (certification schemes and R, D&D programs) have been used as tools in these strategies.

9.1.2 Strategy

To achieve the overall targets for wind energy utilization in Denmark a number of policy instruments have been used. See Table 9.1, Policy instruments used to promote wind turbine technology and installations.

Table 9.1 Policy instruments used to promote wind turbine technology and installations

DEMAND PULL INSTRUMENTS	TECHNOLOGY PUSH INSTRUMENTS
Incentives	Incentives
• Direct subsidies	• R&D programs
• Taxation	• Program for household turbines
• Replacement of small and old turbines	• Test station for wind turbines
• Programs for developing countries	• International cooperation
Other regulation and policy instruments	Other regulation and policy instruments
• Resource assessment	• Approval scheme
• Local ownership	• Standardization
• Agreements with utilities	
• Regulation on grid connection	
• Buy-back arrangements	
• Information programs	
• Spatial planning procedures	

In 1996 the Danish Government's Plan of Action - *Energy 21* - was published. *Energy 21* generally considers new large wind turbines as one of the cheapest technologies for reducing CO_2 emissions from power production. The most economical way is still to erect wind turbines on land, rather than at sea. But area resources on land are limited when housing, nature, and landscape considerations are taken into account. Furthermore, wind conditions at sea are considerably better than at sites on land, and wind turbines erected offshore are expected to become competitive in step with the development of technology.

Energy 21 predicts that a significant part of the expansion of wind power until 2005 will take place on land. As wind turbines become larger and hence more difficult to place in landscapes, the number of new sites will be limited. The increase of wind turbine capacity on land after 2005 will have to be effected, among other things, by renovation of wind turbine areas as well as by removal or replacement of existing wind turbines in accordance with regional and municipal planning. In the longer term, the main part of new development will take place offshore.

The government of Denmark intends to continue its promotion of employment and export opportunities for wind power development by continued research and development.

To provide better opportunities for cleaner energy for individual households located outside the areas that have district heating and natural gas supplies, the government will support development of small wind turbines (household turbines) producing electricity for heat and power. These small wind turbines are seen as a supplement to the general development of wind power.

Energy 21 also comprises some near term initiatives by the Government:

1. reach a decision on development of offshore wind turbines on the background of the action plan for offshore wind turbines completed in July 1997;
2. make wind turbine planning a regular feature of regional and municipal planning;
3. present proposals on revision of the scheme for replacement of older wind turbines;
4. on the basis of the outcome of the ongoing demonstration program on small household turbines, evaluate the opportunities for promoting a development.

9.1.3 Targets

Denmark has one of Europe's best climates for utilizing the wind for power production. Only countries with a coastline direct to the Atlantic Ocean have better conditions in general. Wind energy could, in theory, provide more energy than is consumed in Denmark today. However, economical viability and siting difficulties limit this vast theoretical potential. The useable wind resources in Denmark are partly on land and partly offshore in Danish waters.

Denmark is a densely populated country, so the Danish onshore wind resource is primarily limited by zoning restrictions and the balance between wind energy development and other claims or interests in the open land. As of January 1, 1997, 205 municipalities have finalized their wind turbine planning or proposed such a plan. An additional 39 municipalities announced that they were not able to accommodate wind turbines, and another 31 municipalities have not yet prepared any plans. The estimated capacity in the areas reserved for wind turbine deployment in the approved local plans and the suggested local plans add up to 2,000 MW. About 40% of these sites are in local plans not yet finally approved. The

Danish Energy Agency has analyzed this local planning, and estimates the onshore wind energy potential to be between 1,500 MW and 2,600 MW. The Energy Agency estimates that 2,600 MW of installed wind turbine capacity is able to produce 5.7 TWh annually; or 17 - 18 % of the electricity consumption in Denmark.

Several investigations of offshore wind resources have been prepared since 1977. As a result, two demonstration projects have been finalized. In July 1997 a plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. The plan was prepared by the two utility associations, Elkraft and Elsam, together with the ministry's Energy Agency and Environmental Protection Agency. In the *Plan of Action* eight available areas with water depths up to 15 m are included. The total theoretical installed capacity of these areas is 28,000 MW of which 12,000 MW realistically can be utilized. The wind speeds in the areas allow 3,530 "net full load hours" at the North Sea (Horn's Reef) and between 3,000 and 3,300 hours in interior Danish waters. (Hub height of 55 m and rotor diameter of 64 m is anticipated). This corresponds to an annual electricity production of 30 - 40 TWh. For comparison, the total Danish electricity consumption in 1996 was 32 TWh.

In *Energy 21* the targets for wind energy are 1,500 MW of wind power by 2005 (12% of electricity consumption) and 5,500 MW of wind power by 2030, of which 4,000 MW is offshore (50% of electricity consumption). Total power production from the 1,500 MW will be approximately 3,300 million MWh corresponding to reducing CO_2 emission by 2.8 million tons - or approximately 4.6% of total Danish CO_2 emission.

On September 29, 1997, Svend Auken, Minister for Energy and Environment, published an agreement with the Danish utilities to develop 750 MW more offshore wind power by the year 2008. This was the starting point for large-scale offshore wind farm development in Denmark.

9.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

9.2.1 Installed Wind Capacity

During 1997, approximately 300 MW of wind turbines were installed in Denmark. By the end of 1997 the total installed capacity of wind turbines was 1,146 MW. These data are based on manufacturer information. See Table 9.2.

9.2.2 Installed Conventional Capacity

Maximum power production capacity (excluding wind power) was 9,133 MW. Denmark has relatively few electricity and energy intensive industries. Domestic

Table 9.2 Status of wind turbines in Denmark by the end of 1997. Source: E&M-Data for the Danish Energy Agency based on reports from manufacturers.

OWNER TYPE	TURBINES ADDED	MW ADDED	TOTAL TURBINES	TOTAL MW
Private individuals	420	238.8	1898	564.6
Private cooperations	50	25.7	2163	332.7
Power utilities	44	23.6	681	226.3
Municipalities, industries, others	19	12.0	115	23.3
Total	533	300.1	4857	1146.9

heating is usually not based on electrical power. In 1996 34,939 GWh of electricity was consumed in Denmark, including grid losses. Average electricity consumption per capita was 6,604 kWh (households, industry, etc). A large part of Denmark's electricity is produced in combined heat and power plants (CHP). The total heat production from CHP plants was 86,307 TJ in 1996. Fuel for the power and CHP sector was 357.7 PJ from coal, 16.7 PJ from oil, 29.1 PJ from N-gas, and 48.1 PJ from other sources.

9.2.3 Number / Type, Make of Turbines

During 1997, 533 wind turbines were installed bringing the total number of turbines in Denmark to 4,857. (Numbers are based on manufacturers' information to E&M-Data.) All turbines in Denmark are horizontal axis machines of the "Danish concept" type. There is no available overview of market shares on the Danish market.

9.2.4 Plant Types and Form of Plant Ownership

Wind turbines are typically installed in clusters of three to seven machines. Clusters of wind turbines are preferred by local and regional planning authorities. In a few places, larger wind farms are allowed. Denmark's largest wind farm (in capacity) is Rejsby Hede with 42 machines of 600 kW each.

Different groups own wind turbines: private individual, private cooperations, private industrial enterprises, municipalities and power utilities. Local ownership of wind turbines has been promoted politically by the Danish government and the Parliament. The reason is that wind power's environmental advantages are on a global and national level, whereas, wind power's environmental disadvantages are on a local or neighborhood level. Such local disadvantages can lead to a lack of public acceptance of wind farms. Local ownership of wind turbines (i.e. allowing local farmers, cooperations or companies to benefit from the wind turbines) can secure local acceptance of projects. Co-operatives have been encouraged that spread ownership of a wind turbine among 20 to100 families in the vicinity of the wind turbine.

During the 1980s and early 1990s, most new turbines were installed by co-operatives. Since the mid-1990s, primarily farmers have installed wind turbines. This development is due to several factors:

Figure 9.1 Lynetten wind farm in the harbor of Copenhagen. The farm consists of seven Bonus 600-kW machines.

general interest rates have decreased, prices for wind power electricity have increased slightly, laws for facilitating structural changes in the farming sector have unintentionally left open possibilities for farmers to purchase small pieces of land for wind turbines.

9.2.5 Performance of Wind Power Plants

In 1997, new machines in Denmark (mostly 500 kW and 600 kW) were often placed in areas corresponding to roughness class 1.38 (Beldringe data in the European Wind Atlas); equal to 6.7 m/s in 50-m height as annual mean wind speed. For a 600-kW turbine with a 44 m rotor on a 40-m tower, this means an average production of approximately 1,300 MWh annually corresponding to 2,166 full load hours.

The two demonstration offshore wind farms produced above this average. Vindeby, with 11 Bonus 450-kW machines, has a nominal production of 12,000 MWh (2,424 full load hours) and Tunø Knob with 10 Vestas 500-kW machines has a nominal production of 15,000 MWh (3,000 full load hours).

The total electricity production in 1997 is estimated to be approximately 2,000 GWh, equal to 6.2 % of the total electricity consumption in Denmark. Corrected to a “normal wind year,” this equals 7% of Denmark’s annual electricity production. The wind’s energy index in 1997 was 91%. (Numbers are based on an estimate by E&M-Data.)

9.2.6 Operational Experiences

Technical availability of new wind turbines in Denmark is usually in the range of 98% - 100%.

The Danish wind turbine owners’ association is responsible for recording operational experiences. This activity is financed by the Danish Energy Agency and carried out by the company E&M-Data. The results are published in the association’s magazine “Naturlig Energi”. Operational data are voluntarily reported on 2,600 turbines with a total installed capacity of 574 MW to this database.

Technical lifetime or design lifetime for modern Danish machines is typically 20 years. Individual components are to be replaced or renewed in a shorter interval. Consumables such as oil in the gearbox, braking clutches, etc. are often replaced at intervals of one to three years. Parts of the yaw system might be replaced in intervals of 5 years. Vital components exposed to fatigue loads such as main bearings and bearings in the gearbox might be replaced halfway through the total design lifetime. This is dealt with as a re-investment.

Operation and maintenance costs include service, consumables, repair, insurance, administration, lease of site, etc. The Danish Energy Agency and Risø National Laboratory have developed a model for annual operation and maintenance costs. The model is based on statistical surveys and analyses for 1991, 1994, and 1997. The model includes a large re-investment after the tenth operational year of 20% of the cost of the wind turbine. This re-investment is distributed over the operational years 10 to 20. See Table 9.3.

Four lethal accidents (involving five persons) have occurred during the last 20 years of wind power utilization in Denmark. In 1982 a wind turbine owner was killed when he tried to instal a wind measurement device on the wind turbine’s control system without disconnecting the turbine’s power supply. In 1982, a wind turbine owner died from a fall from his self-constructed wind turbine, where he worked without safety line or safety rail. In 1991, a repair man and lift operator were killed when a rotating blade hit the lift platform on which they worked. The rotor was properly fixed. In 1997, a fitter was killed when working on dis-

Table 9.3 Annual operational and maintenance costs as a percentage of the investment in the wind turbine. Source: Danish Energy Agency and Risø National Laboratory.

MACHINE SIZE	YEAR 1–2	YEAR 3–5	YEAR 6–10	YEAR 11–15	YEAR 16–20
150	1.2	2.8	3.3	6.1	7.0
300	1.0	2.2	2.6	4.0	5.0
500–600	1.0	1.9	2.2	3.5	4.5

mantling an old wind turbine. The latter two incidents led to improved personnel safety regulations.

9.3 MANUFACTURING INDUSTRY

9.3.1 Status / Number / Sales of Manufacturers

Danish-based manufacturers of large commercial wind turbines in the 150-kW to 1,650-kW range are: Bonus Energy A / S, NEG Micon A / S, Nordex Energi A / S, Vestas Wind Systems A / S, Wind World af 1997 A / S, Wincon West Wind A / S. In addition, two companies produce smaller turbines in the 5-kW to 25-kW range. Gaia Wind Energy A / S produces electricity producing machines in the range of 5,5 kW, 11 kW and 22 kW. Calorius-Westrup A / S produces a 5-kW heat producing turbine.

The wind turbine manufacturers had a turnover in 1997 of 5 billion DKK. Total wind turbine manufacturing in Denmark was 968 MW of which 286 MW was sold domestically and 257 MW in Germany. Other large markets for Danish manufacturers are Spain (133 MW), China (74 MW), Ireland (55 MW) and Great Britain (43 MW). Increasingly more manufacturing takes place in foreign subsidiaries and joint-ventures and does not appear in the Danish export numbers.

9.3.2 New Products / Technical Developments

Industrial development in 1997 focused on refining the 500-kW to 600-kW generation of turbines. This includes among other things upgrading the turbines with larger generators and larger rotor diameters. Based on its original 500-kW platforms, NEG Micon A / S has developed a 750-kW machine with a 44-m rotor and a 600-kW machine with a 48-m rotor. Vestas Wind Systems A / S has upgraded its 600-kW machine to 660 kW with a 46-m rotor and its 1.5-MW machine to 1.65 MW. Wind World af 1997 A / S has announced the development of a 2.5-MW machine jointly financed by the European Union.

9.3.3 Business Developments

In 1995, the owners of Nordex A / S sold 51% of the shares to Balcke-Dürr AG. The new company is named Nordex Balke-Dürr GmbH. In 1997, Nordtank Energy Group A / S and Micon A / S merged and formed the company NEG Micon A / S. NEG Micon A / S's shares are listed at the Copenhagen Stock Exchange. After difficulties on the Indian market, Wind World A / S was in 1997 reconstructed under the name Wind World af 1997 A / S. Wind World moved its head office to the city of Aalborg, whereas manufacturing still takes place in the city of Skagen.

9.3.4 Support Industries

A number of industrial enterprises have developed important businesses as suppliers of major components for wind turbines. LM Glasfiber A / S is a world-leading producer of fiberglass blades for wind turbines. DanControl Engineering A / S, Mita Teknik A / S and DWC A / S produce controller and communication systems. Svendborg Brakes A/S is a leading vendor of mechanical braking systems. Also Danish subsidiaries of large international industries such as Siemens, ABB, SKF, FAG, etc. have developed businesses in the wind power industry.

Service and maintenance of the more than 4,000 wind turbines in Denmark is carried out by the manufacturers' service departments, but also a handful of independent service companies have been established. These are companies such as DWP Mølleservice A/S and DanService A/S.

Other industrial service enterprises have created important businesses in servicing the wind power industry. For example, companies are specialized in providing cranes for installations of wind turbines; providing transport of turbines, towers and blades domestically and for export; insurance; etc. The major Danish consultancies in wind energy utilization are BTM Consult Aps, E&M Data, ElsamProjekt A/S, WEA Aps and Tripod Aps. There is one major independent developer of wind farms in Denmark: Jysk Vindkraft A/S, which sells turnkey projects to farmers and co-operatives. (For type-approvals, certifications, and test services see paragraph 9.5.3.)

9.4 ECONOMICS

9.4.1 Electricity Prices

The average electricity price from power distribution utilities varies from 0.295 to 0.442 DKK/kWh. For private consumers (connected to the 400/230-Volt distribution grid) a number of taxes are added to this price. The electricity tax is 0.40 DKK/kWh. The CO_2 tax is 0.10 DKK/kWh. The SO_2 tax is 0.009 DKK/kWh. In addition, a 25% VAT is added. In 1997, the average consumer price for Danish low voltage customers was between 1.0 DKK/kWh and 1.2 DKK/kWh.

9.4.2 Invested Capital

It is difficult to calculate exactly the total capital invested in wind power over the years. In the *1996 IEA Wind Energy Annual Report* a total investment of 7.6 billion DKK was estimated. If 300 MW was added in 1997 at a cost of 6.5 million per MW, a total of about 2 billion DKK was invested in 1997. This makes a total of 9.6 billion DKK.

9.4.3 Turbine/Project Costs

Ex works cost of wind turbines has decreased significantly with the latest 600 generation kW (43 - 44 m rotor diameter). For new 600-kW machines the ex works cost is typically 3.15 million DKK.

Additional costs depend on local circumstances, such as condition of the soil, road conditions, proximity to electrical grid su b-stations, etc. Additional costs on typical sites can be estimated as 20% of total project costs. Only the cost of land has increased during recent years. See Table 9.4.

In 1991, Elkraft inaugurated the Vindeby offshore wind farm with 11 Bonus 450-kW machines. Today, the farm is owned and operated by the power utility SEAS. The total cost of this project was 66 million DKK excluding extraordinary costs as R&D part of the project, investigation of the impact on fish, etc. Annual production is estimated to 12,000 GWh.

In 1995, Midtkraft in the Elsam area installed a 5-MW wind farm at Tunø Knob consisting of 10 Vestas 500-kW machines. The total cost of this project was 73.8 million DKK excluding extraordinary costs, such as removal of mines, investigation of the impact on birds, etc. Annual production was estimated to 15,000 GWh.

Table 9.4 Cost of a typical 600-kW wind turbine project. Source: Danish Energy Agency and Risø National Laboratory.

COMPONENT	AVERAGE DKK (000)	AVERAGE DKK (000)
Turbine ex works	3146	161
Foundation	149	20
Grid connection	288	70
Electrical installations	20	13
Communication	14	9
Land	103	84
Roads	39	44
Consulting	36	49
Finance	20	27
Insurance	94	53
TOTAL	3909	

9.5 MARKET DEVELOPMENT

9.5.1 Market Stimulation Instruments

A production subsidy of 0.10 + 0.17 DKK/kWh is paid to private wind turbine owners. There are limitations to the wind farm developments to which the above incentives apply. Private individuals, for example, are only allowed to grid-connect one turbine, and this must be placed on the owner's land. Similarly each shareholder in private co-operatives is limited to ownership of shares equal to 30,000 kWh. The shareholders must live in the same municipality where the turbine is installed. The utilities receive 0.10 DKK/kWh in production subsidy.

Buy-back rates are related to the utilities' production costs (tariffs). A law requires power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production costs. Average production cost in 1997 was 0.379 DKK/kWh (weighted with wind power capacity in each distribution utility). Thus, average buy-back rate in 1997 was 0.322 DKK/kWh. Since most Danish electricity production is based on coal, the wind energy buy-back rates are closely related to the coal prices on the world market. This represents a risk for the wind energy producers. In the early 1990s, world market coal prices dropped, and a number of wind turbine projects had difficulties. As a result, the installation of new turbines in Denmark decreased from 81 MW in 1990 to 29 MW in 1993. On the other hand, if the world market coal price increases, wind turbine owners will benefit - to a certain degree. If coal prices increase significantly (or if any other significant improvement of the return of investment on wind energy occurs), the government would probably reconsider the 0.27 DKK/kWh production subsidy.

Favorable taxation schemes have been used to stimulate private wind turbine installations. The taxation schemes have changed over time. Today, income from wind turbines, by and large, is taxed as other income.

Private persons and companies can choose between two models for taxation of their income from wind turbines or shares in wind turbines. Owners of individually-owned or company-owned turbines often choose to pay income taxes in the same way as income from other investments. That is full tax of the income, but with deductions from the annual depreciation of the investment and expenditures to operations and maintenance costs, according to the usual tax regulation. Shareholders in private co-operatives can chose a “simplified model,” according to which the first 3,000 DKK of income from sale of wind power is tax free and 60% of the rest is taxed with the usual marginal income tax percentage; usually 60%. No deductions are allowed. The simplified income tax model gives a tax incentive for owners of small shares in a wind turbine. The smaller the share, the larger the relative incentive. This is used as an instrument to spread the ownership of wind turbines to as many citizens as possible. For owners of turbines acquired before the present taxation rules, a number of other rules exist.

All wind turbines with an annual turnover of more than 20,000 DKK must have a VAT-number. The wind turbine owner or the co-operative charges a 25% VAT on the electricity sold to the utility, but not on the 0.27 DKK subsidy. The wind turbine owners transfer this collected amount to the government.

9.5.2 Planning and Grid Issues

Spatial (or land-use) planning establishes a framework for siting wind turbines in the open land and balances the interest of wind energy against other interests, including how existing urban features and landscapes can best be protected. Tasks related to environmental protection are increasingly integrated in the work of spatial planning. Spatial planning in Denmark is carried out at three levels: local and municipal planning in the municipalities, regional planning in the counties, and national planning co-ordinated by the Ministry of Environment and Energy.

The Ministry can influence planning through regulation, national planning directives, and the dissemination of information. The location of wind turbines and high-voltage transmission lines in rural landscapes are two examples in which the Spatial Planning Department influences planning.

All counties have prepared guidelines for regional planning. These guidelines lay down the overall conditions for wind turbine deployment in each particular region / county.

Municipalities (local planning authority) prepare local wind turbine plans, issue zoning permissions and installation permissions according to the law on spatial planning. Local wind turbine plans typically prescribe where turbines are to be installed (distances to roads, dwellings, etc.), how they are to be installed (individual machines, clusters, parks), and their appearance (tower type and color).

In the spring of 1994, the Minister of Environment and Energy issued a circular requesting local planning authorities (municipalities) to initiate a local planning of wind turbine deployment in their area. The circular anticipated a time frame for the draft plan of July 1, 1995. Hereafter each draft plan must pass through a traditional hearing process and political decision process in each municipality.

Installation of land-based wind turbines presumes no specific environmental assessment. The balancing of the interests of wind energy utilization against other interests in the open land are usually contained in the legislation on each area.

The law on environmental protection specifies some proximity guidelines, such as distance between wind turbine and local features such as: coastline - 300 m; lakes and streams - 150 m; forests - 300 m; ancient monuments - 100 m; and churches - 300 m.

A wind turbine’s noise emission must be verified according to the rules in the

Ministry of Environment and Energy's statutory order no. 304. According to this order, noise from wind turbines must not exceed 45 dB(A) outdoors at the nearest habitation in rural areas, and 40 dB(A) in residential areas and other noise sensitive areas. As tonal noise is often a source of annoyance 5 dB(A) is added to the measured broadband noise if tonal noise is clearly audible at the location where the noise level is being measured. A simple method for calculating the noise emission of a wind turbine is specified in the statutory order.

According to a statutory order, the costs of grid connection of wind turbines are split between the wind turbine's owner and the power utility. The wind turbine owner must bear the costs of low voltage connections, whereas utilities must carry the costs for reinforcement of the 10-20kV power lines when such is needed.

9.5.3 Institutional Factors

The Danish approval scheme for wind turbines has been established to fulfill a common desire from wind turbine manufacturers, owners and authorities for a coherent set of rules for approval of turbines installed in Denmark. An approval is partly based on a type approval of the turbine and partly on a certified quality assurance system which, as a minimum, describes production and installation of the turbine. Today all manufacturers have an ISO9000 quality assurance system.

A set of rules have been developed and adopted in *Teknisk Grundlag for Typegodkendelse og Certificering af vindmøller i Danmark* (Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark). Several recommendations are affiliated with the Technical Criteria. In the future, the recommendations are to be replaced by IEC or CENELEC standards, and the Technical Criteria are to be harmonised on a European level.

The Danish Energy Agency is responsible for administration of the approval scheme. On behalf of the Danish Energy Agency, a group at Risø National Laboratory acts as secretariat and information center for the approval scheme. To assist the Danish Energy Agency, an advisory committee is formed with representatives from the wind turbine manufacturers' association, the wind turbine owners' association, insurance companies and the power utilities. For discussion of technical and administrative matters regarding the approval scheme a technical committee is formed consisting of the authorized bodies. As several authorized bodies are non-Danish enterprises, the technical committee's meetings are held in English. Minutes and other communications from the committee are primarily distributed in Danish. A separate technical committee is set up for household turbines.

Since 1979, Risø has been authorized by the Danish Energy Agency to issue licenses or type-

approvals for wind turbines, including the test and measurements required for the approvals. Today the market for these services is liberalized and private enterprises can be authorized to perform type approvals, certifications, tests and measurements. This market is open for international competition and several foreign enterprises are active. See Table 9.5.

9.5.4 Impact of Wind Turbines on the Environment

Utilizing wind power is one of the cheapest methods of reducing CO_2 emissions from electricity production. Production from the large-scale offshore wind farms will be approx 2.5 million MWh CO_2 free power per year and give a yearly reduction of 2.1 million tons in the CO_2 emissions or 17.5% of the total national reduction objective for 2005.

Table 9.5 Bodies authorized by the Danish Energy Agency to provide services under the Danish scheme for certification and type-approvals for wind turbines (by end of 1997).

SERVICE	AUTHORIZED BODY
Production and installation certification	Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Insurance Dansk Standard
Type approvals	Risø, Approval Office Germanischer Lloyds
Basic tests	Tripod Consult Aps Risø, Test & Measurements
Power curve measurement	DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Tripod Consult Aps Risø, Test & Measurements
Noise measurement	DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Wind Consult GmbH DELTA Akustik & Vibration + bodies approved by DELTA

Although modern wind turbines conform to current noise requirements, their size alone means that it is not appropriate to install them too close to inhabited areas. As there are very few open areas in Denmark without dwellings, utilizing the open sea has great advantages.

The possible impact on wildlife is one important matter. Studies on land-based wind farms conclude that wind turbines do not pose any substantial threat to birds and other wildlife. All of the appointed areas for offshore wind farms lie outside of EU bird sanctuaries but there are also important areas for birds in several of the sites. Studies have already been conducted of possible impact on sea birds at the Tunø Knob installation. While the final result of the studies is not yet available, the studies reveal that the eider has not been frightened away from the Tunø Knob area by the establishment of an offshore wind farm. The eider ducks that winter there are much more influenced by the presence of food than by the presence of the wind turbines.

9.5.5 Financing

Availability of capital for wind power projects is not a problem. Financial institutions compete efficiently in this market and different financial packages have been developed.

In 1997, individually owned projects (farmers) typically finance projects over 10 years with an annual interest rate of 6% to 7%. Co-operative owned projects typically can achieve a bit lower interest rate than individually owned projects.

9.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

9.6.1 Funding Levels

The Danish governmental sponsored programs consist of two programs.

9.6.1.1 Ministry of Environment and Energy's Energy Research Program (EFP).

During recent years a part of the research program has been allocated to energy issues in Eastern Europe and the former Soviet Union. The Energy Agency administers the program. Practically all projects are initiated through the annual call for proposals issued by each Research Committee. The deadline for project proposals is normally in the beginning of September. Projects are normally run over two or three years and funding will be given by the end of each year. In almost all projects, several partners participate and industrial participation and co-financing is encouraged. The Danish Energy Agency typically finances 50% to 85% of the total cost. In the 1997 round (processed in 1996), five projects were supported with a total amount of 13.35 million DKK. In the 1998 round (processed in 1997) of the energy research program (EFP), nine projects were initiated with a total support from the Danish Energy Agency of 14.15 million DKK.

9.6.1.2 Ministry of Environment and Energy's program for development, demonstration and information of renewable energy (UVE).

The Energy Agency administers the program. The program so far has been renewed every three years. In the present period, projects are initiated through a standing call for proposals. There is no deadline for project proposals, but they are debated at the regular meetings in the Technical Advisory Committee. Projects are always shorter that three years. In 1997 projects were supported by the Danish Energy Agency with a total of 23.6 million DKK.

For the program areas of wind energy, biomass, and solar energy, the Ministry and the Energy Agency are advised by Technical Advisory Committees. The Technical Advisory Committee on Wind Power is identical with the Research Committee in the Energy Research Program. This ensures a good co-ordination of the activities within the two programs.

As a part of this program, the Danish Energy Agency operates test stations for different renewable energy technologies. One is the Test Station for Wind Turbines at Risø National Laboratory. The activities of the Test Station for Wind Turbines are negotiated each year. The budget for the Test Station task at Risø was 7.9 million DKK in 1997.

The total budget for the Danish Energy Agency's wind energy activities amounted to 45.6 million DKK. This is a small increase compared with recent years.

9.6.2 Priorities

The overall aims of the energy research program are the following.

1. Contribute to realization of the goals of the energy policy through short-term research activities;
2. Support long-term and strategic research, which significantly can improve the Danish energy situation in a long-term perspective and establish the basis for new political initiatives;
3. Contribute to achieving other political goals than those affiliated with energy issues, such as the country's economical development, environmental improvements, industrial development, employment, export, etc.;
4. Contribute to a global sustainable development through dissemination of Danish developed technology and knowledge adapted for the conditions in developing counties and countries in East Europe.

At least one-third of the resources of the energy research program must be aiming at long-term perspectives (beyond year 2005). Project titles in the 1997 round of the research program were the following.

1. Program for research in aeroelasticity;
2. WAsP engineering version 1.0 DK – Wind conditions for wind turbines;

3. Isolated systems with wind power;
4 Experimental investigation of extreme loads;
5. Adaptation of Danish wind turbine technology to Russian conditions.

Descriptions (in Danish) of the projects are available on the Danish Energy Agency's www-pages.

The overall aims of the renewable energy development program's wind part are:

1. To promote the technical possibilities for utilization of wind power in Denmark through research, development and demonstration of new and better wind power technology;
2. To support the optimal utilization of the available sites;
3. To participate in removing barriers for sustainable utilization of wind energy;
4. To strengthen the Danish contribution in international cooperation;
5. To stimulate Danish industrial development and export.

The list of project titles is very long, and contains very different projects: development projects, demonstration projects of small household turbines, information activities, economy surveys, in co-financing of some EU-projects, etc.

The Test Station for Wind Turbines activities for 1997 were more or less the same as the preceding years and comprised:

1. Information activities;
2. International cooperation with other test stations for wind turbines;
3. Secretariat for the Danish certification and type-approval scheme;
4. Spot-check of type approved turbines;
5. Inspections of major break-down of turbines;
6. International standardization;
7. Development of test methods for wind turbines;
8. Development of test methods for blades;
9. Participation on the IEA annex on Round Robin test of a wind turbine.

9.6.3 New Concepts

During recent years, a development and demonstration program for so-called "household" turbines in the range 5 to 25 kW has been a part of the Danish Energy Agency's development program (UVE). A number of concepts different from the traditional "Danish concept" have been developed including a multi-bladed turbine, a two-bladed teeter hub design, and a two-bladed stiff hub design for a heat producing machine. Almost 100 such small turbines have been installed within or outside the demonstration program.

9.6.4 Offshore Projects

In the years to come, utilization of the Danish offshore wind resources will have a high priority in the Danish energy research and development programs. Today two demonstration farms are in operation: Vindeby 4.95 MW and Tunø Knob 5 MW.

Studies financed by power utilities, Danish Energy Agency, and EU/JOULE indicates a substantial cost reduction for new 100 - 200-MW offshore projects: 56% reduction compared to Vindeby.

More accurate assessment of the offshore wind climate and prediction of wind loads are important research issues.

9.6.5 International Collaboration

International cooperation on wind energy R&D is emphasized by the Danish Energy Agency. Denmark has participated in the international cooperation in IEA R&D Wind since its establishment.

Danish universities, research centers, power utilities and manufacturing industry participate in the European Union's RTD programs. No quantitative data are available.

Active Danish participation in international standardization in IEC and CEN / CENELEC has a high priority and R&D efforts supporting international standardization are encouraged.

CHAPTER 10

10.1 GOVERNMENT PROGRAMS

10.1.1 Aims and Objectives

The Finnish government published a new energy strategy in 1997. As unemployment in Finland is still high, energy politics is dominated by the wish for economic development and better employment. The economic arguments dominate over environmental discussions such as the international discussions of CO_2 emissions.

Renewable energy has, in general, good support in national energy politics, but the interest is focused on the use of bioenergy and especially wood or other residue from the forest industry. Wind energy is considered less significant. Wind energy has local support in some areas but only on the Åland islands has the support been transformed into a real political issue.

Wind energy is still seen only as a marginal energy resource, which could reach a level of “some” percent of energy production only after 2015.

10.1.2 Strategy and Targets

Wind energy has been supported by a specific wind energy action program since 1993, that aimed at having 100 MW by the year 2005. The main actions in this program have been an investment subsidy and a national energy research program. According to preliminary information, the Ministry of Trade and Industry will renew the action program and change its emphasis from technology development to dissemination.

The wind energy action program, published in 1993, aims at 100 MW by the year 2005. The new energy strategy does not have a specific target for wind energy but in the different scenarios the share varies between 1 and 4 TWh per year.

10.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

10.2.1 Installed Wind Capacity

1997 showed some sign of a new start for wind energy development in Finland. Installed capacity rose by 4.6 MW or 63 % to almost 12 MW. Nearly all turbines were, however, installed by operators with previous experience in wind energy and it seems difficult to get the interest to spread across the country. See Figure 10.1.

Wind energy activities seem to be concentrated in three different regions. In the autonomous region of the Åland islands in the Southwest, development is focused around a specific wind energy co-operative with more than 2,000 shareholders and significant local support. Although, the co-operative does not own all the turbines installed, it is, however, the dominant player in the region.

In the area around the northern part of the Gulf of Bothnia several players are active. The most significant is a utility with a clear strategy to develop wind energy ”step-by-step.” The 1.2 MW installed this year is already the third initiative by the utility. As the utility is clearly committed, the interest has spread to the neighboring municipalities and utilities which are taking action.

The third area with significant wind energy activity is Lapland in northern Finland. Here the power company Kemijoki is developing both technology and its own strategies to have a significant share of wind energy in the future. See Table 10.1.

10.2.2 Comparison With Gross Electricity Consumption

The annual gross power consumption rose in 1997 to 73 TWh. The annual

Table 10.1 Installed capacity and production of wind energy in Finland.

YEAR	NEW CAPACITY (MW)	TOTAL CAPACITY (MW)	PRODUCTION (GWh)
1992	-	1.6	2.4
1993	3.0	4.6	4.4
1994	-	4.6	7.2
1995	1.8	6.4	10.8
1996	0.9	7.2	11.0
1997	4.6	11.8	16.6

growth is expected to be about 2–4 % for the next decades. The current power production capacity during years with normal rainfall amounts to about 75 TWh.

10.2.3 Numbers, type and ownership of machines

Eight new turbines were installed in Finland during 1997 bringing the total number to 31. All of them are of Danish manufacturing except for one German turbine installed in 1997. All installations are single turbines or small groups of up to four turbines. Most turbines, so far, are owned by power companies, utilities or companies partly owned by utilities. Still, a large share is owned by co-operatives or specific wind energy companies. See Table 10.2

10.2.4 Performance and Operational Experience

Of the existing 31 wind turbines, two are considered test or research turbines. These are not operated under commercial terms but are undergoing testing of materials and components and therefore have lower performance than the other turbines.

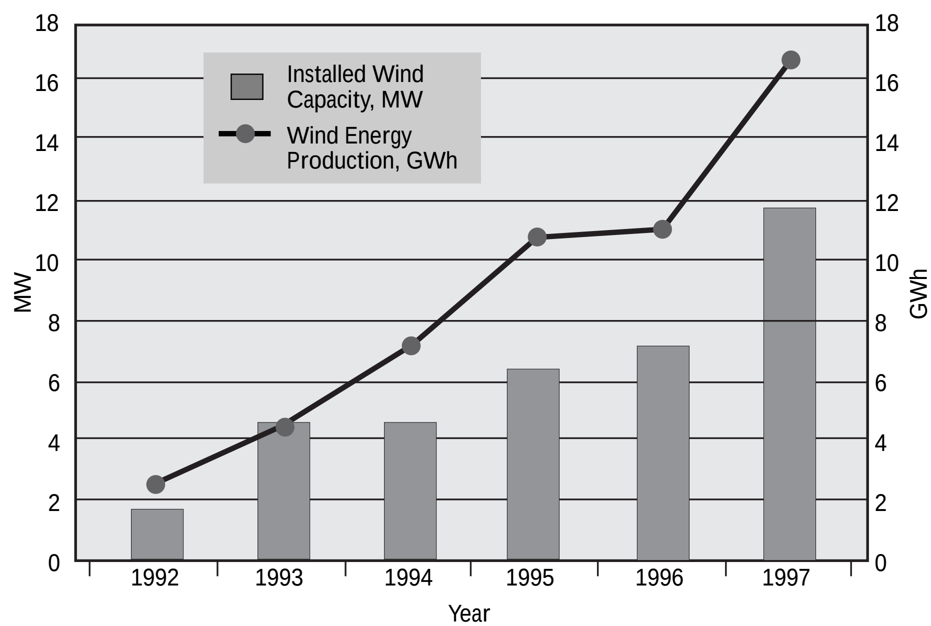

Figure 10.1 Installed wind energy capacity in Finland.

Table 10.2 Number of new wind turbines in Finland installed each year.

YEAR	<100 kW	200–300 kW	450–600 kW	TOTAL
1991	1	4		5
1992		1		6
1993		11		17
1994				17
1995			4	21
1996			2	23
1997			8	31

The other turbines under standard operation show typical availabilities of 92–100%, with an average availability of 97%. In 1997, one turbine had a longer downtime period due to a lightning strike.

Some turbines have had shorter downtime periods due to the formation of ice on the blades, losing some production during the winter months. This concerns turbines in southern Finland where icing events are rare and passing so machines are not specially equipped to prevent this.

10.3 MANUFACTURING INDUSTRY

10.3.1 Status of Manufacturing Industry

There are no wind turbine manufacturers in Finland. However, main components such as gearboxes and induction generators are produced and sold to the main wind turbine manufacturers. Also materials like steel plates and glass-fibre are sold to the wind industry. The total turnover of this “sale of components” is estimated at about FIM 300 million in 1997. The sales have increased steadily during the 90s.

The industry has been very successful in supplying components to medium-sized wind turbines up to 750 kW. The transition towards larger wind turbines of 1–1.5 MW might change the situation. The components industry is developing its product range to fit the large-scale turbines. This has required some investments in new production facilities.

In cooperation with Danish manufacturers, a blade heating system for wind turbines operating under icing conditions is being developed into a new commercial product. Production facilities for this purpose are being started up.

10.3.2 Support industries

Four Danish manufacturers have selling agents operating in Finland. Further, there are several small and one large consulting company working in the field of wind energy. They carry out a wide range of activities, such as feasibility studies, engineering, environmental analyses and potential studies. They are also offering full contractual and O&M services, but, because of the slow development of the market, they have not yet been able to carry out these activities.

10.4 ECONOMICS

Wind produced electricity is mostly rewarded with the average marginal costs of purchase for the utilities. This amounts to about FIM 0.15–0.20 / kWh depending on the utility. No fixed price has been established. Some utilities offer their customers a ”green power tariff” with an extra charge of FIM 0.02–0.04 / kWh that is allocated directly (minus VAT) to the wind energy producer. The successes of these tariffs have, however, so far been modest.

Average prices of electricity for the industry is in the range of FIM 0.15–0.25 / kWh and for domestic consumers, FIM 0.40–0.60 / kWh.

The electricity market was liberalized in 1995 and, from the beginning of 1997, small consumers can also participate in the market. Power sales and distribution are separated and consumers can buy their power from anywhere and transfer the power through the common grid. So far this has been administratively impossible for small customers but will eventually be made easier.

10.5 MARKET DEVELOPMENT

10.5.1 Market Stimulation Instruments

The Ministry of Trade and Industry (MTI) can subsidize installations by up to 40% of the investment. The percentage is decided upon on a project-by-project basis and handling time has been rather long, up to over half a year. Preference is given to projects that include some kind of technical innovation.

From the beginning of 1997 the taxation was moved from energy production to energy consumption. Where the production tax was CO_2-related, the consumption tax is a general electricity tax that does not consider fuel or any environmental impact. However, wind energy and other small local energy production receives extra support of FIM 0.02 / kWh, corresponding to the electricity tax for industrial consumers.

10.5.2 Planning and Grid Issues

According to the Electricity Market Act from 1995, all power plants have to get access to the public grid according to general cost pricing.

When the energy market is opened and Finland will join Nordpool, the Nordic power pool, electricity prices might rise somewhat in general, but prices will still be lower than the costs for wind energy.

10.5.3 Institutional Factors

Regional Environmental Centres have authority regarding planning and environment issues in the respective regions. Some of them have a strong negative attitude towards wind energy. Several prospective projects have been stopped, either by local or regional councils, due to the difficulty in getting planning permission.

A working group of the Ministry of Environment published in 1997 a draft report concerning how wind turbines should be considered in local and regional planning and which factors should be concerned in the handling of applications for planning permissions for wind turbines. The final report is expected soon and is directed towards local and regional planning authorities.

10.5.4 Impact of Wind Turbines on the Environment

The visual impact on the landscape is the most difficult planning problem related to

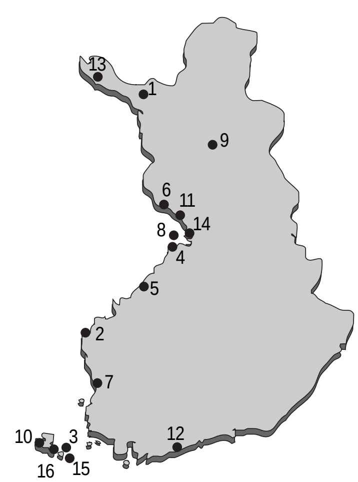

Figure 10.2 Location of installed wind turbines in Finland (See Table 10.3 for key).

wind energy and, after economics, this is the most significant obstacle to development. The reason is simply that the regions with the most wind are also very picturesque and environmentally valuable. In particular, the Finnish archipelago is significant in shaping the national identity. Further, many Finns have summer cottages, in the countryside, especially in the archipelago and other coastal regions. At their summer cottages people want to have a close relation to untouched nature. They do not want modern technology, like wind turbines, in close vicinity.

10.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

10.6.1 Funding levels

Most of the R&D related to wind energy has been carried out within the national energy research program NEMO2 that has been operating since 1993, funded by the Technical Development Centre TEKES.

Ordinary R&D projects can get national funding up to 50 %. Under certain conditions the support can reach 60 %, e.g. in the national research programs. R&D carried out by the industry can also get funding up to 60 %.

10.6.2 Priorities

Priority is given to projects that have an industrial benefit, i.e. projects leading to results that can be rapidly utilized by the industry. An indicator of this is usually the amount of direct financing by the industry. Regarding wind energy, priority is given to projects that strengthen the position of the component industry and projects that increase the value added of material supplies.

10.6.3 Offshore Developments

R&D on offshore installations is focused on foundation technology. In addition to wave and wind loading, the foundation also has to take ice loads into account.

Table 10.3 Installed wind turbines in Finland.

LOCATION	NO. x RATING, kW	YEAR INSTALLED
1. Paljasselkä	65	1991
2. Korsnäs	4 x 200	1991
3. Sottunga	225	1992
4. Siikajoki	2 x 300 2 x 600	1993 1997
5. Kalajoki	2 x 300	1993
6. Kemi	3 x 300	1993
7. Pori	300	1993
8. Hailuoto	2 x 300 2 x 500	1993 1995
9. Pyhätunturi	220	1993
10. Eckerö	500	1995
11. Kuivaniemi	500	1995
12. Kopparnäs	50	1995
13. Lammasoaivi	2 x 450	1996
14. Ii	500	1997
15. Kökar	500	1997
16. Lemland	4 x 600	1997

The sea in offshore locations is covered with ice up to 100 days every year. To make matters worse, the whole ice field is moving and building ice ridges on the shorelines that can reach up to 30 m height. Despite these difficulties, large-scale offshore installations are possible with foundation technology used in other applications, such as lighthouses.

R&D on offshore technology used to focus on the numerous small rocks and islands, that were recognized as natural foundations for wind turbines. Due to environmental concern it has, however, been impossible to get planning permission for any such project.

Figure 10.3 One of the two Bonus 450-kW wind turbines, with ice preventing systems in the blades, that are installed on top of the fell Lammasoaivi in northern Finland (Long. 21º20', Lat. 68º50').

10.6.4 International Collaboration

Most international R&D collaboration is carried out within the European Union's research programs. In 1997, Finnish companies and research institutes took part in at least seven different projects. There is also active participation in the dissemination programs.

R&D projects funded by the EU programs can be co-funded up to 20% by TEKES, if the projects fit in with the general targets for technical R&D, that are described above.

A working group for bilateral cooperation with Russia in the field of renewable energy was started in 1995. The main objectives are to maintain the research potential in Russian research institutes and to assist broader international cooperation.

CHAPTER 11

GERMANY

11.1. GOVERNMENT PROGRAMS

11.1.1. Aims and Objectives

The actual program, the “4th Program for Energy Research and Technology“, has been in force since 1996 and has again been carried out by the Federal Ministry for Education, Science, Research and Technology (BMBF).

The program follows consistently the goals of the former programs to conserve limited resources, to improve the security of the German energy supply, and to protect the environment and the climate. Two general objectives are emphasized.

1. Creation of the necessary prerequisites;
2. Contribution to the modernization of the national economy, to maintain the German technology position and to improve the exports.

Research and technology policy should set boundary conditions which allow the development of a sufficiently broad spectrum of technical options.

11.1.2 Strategy

The strategy of the R&D funding of the 4th Program follows three aims.

1. Improvement of the performance and reliability of existing techniques.
2. Development and demonstration of technological concepts for the future.
3. Support of basic research for 1 and 2 above.

In the short and medium term, an important contribution to decrease energy consumption and to reduce CO_2-emission is expected from the improvement of thermal power stations and a further use of rational energy. From today’s point of view nuclear power has one of the largest potentials to reduce CO_2-emission, but its further utilization is politically disputed. The government politics maintain that this energy source should contribute to the “energy-mix“ of Germany.

In the medium or long term, renewable energies are expected to contribute significantly to the German energy supply and to reduce CO_2-emission. Technically rather advanced, but not in all cases economically competitive, is the utilization of heat (solar thermal, heat pumps, biomass) and electricity (wind power, waste contribution, biomass, photovoltaic). A long term possibility for the energy supply is controlled nuclear fusion. Here R&D is considered to be important and thus is supported strongly by the program.

The full range of strategy measures covers various technologies. For this report, the item Renewable Energies and Rational Use is of special interest. Table 11.1 shows the technologies of this part and the planning of the budget until 2001.

11.1.3 Targets

The “4th Program for Energy Research and Energy Technologies“ is related to the political target of the German government to reduce the CO_2-emission by 25% by the year 2005 from 1990 levels. The sustained implementation of the program will contribute to reaching this target together with measures taken in other fields, such as traffic. German industry will contribute to the government obligation, as declared on March 1996, by reducing its specific CO_2 emission by 20 % by the year 2005 compared to 1990 levels.

Governmental targets for wind energy in Germany are not specified. In governmental publications, a yearly wind electricity production of up to several per cent of the electricity production are considered to be possible. Within the “250 MW Wind“

Table 11.1 Budget for “Rational Eenrgy Use Saving of Fossil Energy for Consumers” and for Renewable Energies 1996–2001, status 8/97, BMBF and Ministry of Agriculture (Biomass)

TECHNOLOGY	1996	1997	1998	1999	2000	2001
Rational Energy Use, Saving of Fossil Energy for Consumers						
• Solar thermal power, heating of buildings	35.0	29.0	29.0	28.5	29.3	29.5
• Heat Storage	2.0	2.0	1.5	1.5	1.0	1.0
• Energy-saving industrial processes	13.1	8.0	8.1	7.5	7.5	6.5
• Large research facilities	20	20	20	22	22	24
Total	70.1	59.0	58.6	59.8		
Renewable Energies						
• Photovoltaic	59.2	64.0	64.0	64.0	64.0	64.0
• Wind Power (incl. 250 MW-Programme)	49.9	35.0	35.8	37.2	37.8	40.1
• Biomass	5.7	10.0	10.0	11.0	13.0	13.0
• Geothermal Energy and other renewables	4.2	3.0	4.0	3.7	4.0	4.5
• Application systems for southern climatic conditions	22.4	14.0	13.5	5.3	4.0	3.0
• Large research facilities	67.1	78.0	78.5	77.4	80.4	79.0
Total	208.5	204.0	205.8	198.6	203.2	203.6

Program a total rated power of about 390 MW will be reached (250 MW refers to the WECS power at 10 m/s wind speed), corresponding to a yearly electricity production of all turbines (including the early, smaller WECS) of roughly 1800 h x 390 MW ± 10% = 0.7 x 10^9 kWh ± 10%, or almost 0.2% of the total actual produced electricity.

Two German Federal States published specific targets. Lower Saxony: 1000 MW by the year 2000 (status end 1996: 426 MW) and Schleswig-Holstein: 1200 MW by the year 2010 or 25% of Schleswig-Holstein electricity consumption (by the end of 1996, 631 MW corresponding to 8.6% of Schleswig-Holstein’s electricity consumption).

11.2. COMMERCIAL IMPLEMENTATION OF WIND POWER

11.2.1 Installed Wind Capacity

By December 31, 1997, the number of installed wind turbines was 5,193, with a total rated power of 2082 MW. Some 849 turbines with a total of 534 MW were installed in 1997. Compared to 1996, the total rated power increased by nearly 25%.

The total number of turbines in operation by December 31, 1997 within the “250 MW Wind“ Program was 1,511 (29% of all WECS), corresponding to a total of 346 MW (16% of the total capacity). The development of wind power in Germany is shown in Table 11.2. The distribution of wind power for the 16 German states is given in Table 11.3.

Table 11.2 Development of Wind Power in Germany; “250 MW Wind” and total.

DATE	NUMBER OF WECs		RATED POWER (MW)		WIND ELECTRICITY PRODUCTION (10^9kWh)	
	250 MW WIND	TOTAL	250 MW WIND	TOTAL	250 MW WIND	TOTAL
31.12.1989	15.0	256.0	1.4	20.0	0.0003	—
31.12.1990	187.0	506.0	30.8	60.0	0.016	0.58
31.12.1991	439.0	806.0	72.2	111.0	0.089	0.13
31.12.1992	738.0	1211.0	121.3	183.0	0.201	0.28
31.12.1993	1058.0	1797.0	183.9	334.0	0.302	0.5
31.12.1994	1317.0	2617.0	255.5	643.0	0.462	1.0
31.12.1995	1466.0	3528.0	311.0	1120.0	0.543	1.5
31.12.1996	1552.1	4326.0	335.0	1546.0	0.523	2.0
31.12.1997	1511.0	5193.0	343.8	2082.0	0.580	3.0–3.3

The total rated power wind turbines in the three coastal Federal States Niedersachsen (Lower Saxony), Schleswig-Holstein, and Mecklenburg-Vorpommern was 1,320 MW (63% of the total installed power) corresponding to 3,280 WECS (63% of the total number of WECS). The regional distribution of WECS operating within the “250 MW Wind“ Program, and their rated capacity for different rated power classes by December 31, 1995, was evaluated. See Figure 11.1.

11.2.2 Comparison with Conventional Public Electricity Consumption

The total public electricity consumption in Germany for 1997 was 467x10^9 kWh. According to the data given in the Table 11.1, it follows that during 1997 wind power contributed 0.7% to the German public electricity consumption (1996 : 0.5%). The contribution of all renewables, mostly hydro-power, is around 5%.

11.2.3 Numbers / Type, Make of Turbines / Ownership

For the number of turbines installed in 1997 and in total we refer to section 11.2.1, Table 11.2 and 11.3 as well as Table 11.5. The statistics of different WECS types are available for WECS within the “250 MW Wind“ Program, see Figure 11.2. The Figure represents the situation from the beginning of the program in about 1990 until today. In 1990 many smaller WECS - no longer on the market - came into operation. Thanks to the “250 MW Wind“ Program the statistics of ownership are known. See Table 11.4. Private individuals and trade and industry (including the so called power-investors) erected by far the largest part of the total rated power, but trade and industry is leading with the average WECS size.

These numbers again reflect the development of wind power in Germany since 1989 / 90: Farmers and private individuals bought the smaller WECS available at that time, whereas today trade and industry, mostly new firms, invest in projects with

Table 11.3 Distribution of wind power for the German Federal States .

FEDERAL STATE	RATED POWER		NUMBER OF WECS	
	TOTAL	1997	TOTAL	1997
Schleswig-Holstein	630.8	90.650	1523	136
Niedersachsen	565.2	137.160	1460	202
Nordrhein-Westfalen	245.6	87.050	736	142
Mecklenberg-Vorpommern	124.6	39.550	297	63
Brandenberg	90.8	16.330	212	32
Hessen	115.4	43.200	231	66
Sachsen	99.0	28.900	206	48
Rheinland-Pfalz	58.9	21.300	171	35
Sachsen-Anhalt	61.1	34.810	136	63
Thüringen	33.9	15.800	73	30
Hamburg	16.4	5.000	37	9
Bayern	15.0	5.600	43	9
Saarland	5.8	0.600	13	1
Baden-Württemberg	12.6	6.220	35	10
Bremen	5.75	1.800	17	3
Berlin	0.75	0.000	3	0

WECS of the actual commercial 500- to 600-kW class of European manufacturers.

11.2.4 Performance and Operational Experience

The average technical availability for 1996 was again more than 98 %. That means an average stand-still time of about 80 h per year per unit. The performance of wind turbines in Germany is recorded in some detail in the “250 MW Wind“ Program. For this purpose, ISET carries out a Scientific Measurement and Evaluation Program WMEP on behalf of BMBF.

Figure 11.3 shows examples of failure statistics and statistics of repaired and exchanged parts. More than 50 % of the causes of failure are identified with component failure and control system of the WECS, a quarter of the causes are identified with external influences (high wind grid failure, lightning, icing).

11.3 MANUFACTURING INDUSTRY

11.3.1 Market Shares

Table 11.5 shows the shares of the suppliers on the German market in 1997. Turbines with a rated power of between 400 and 750 kW were sold almost exclusively. In all 703 turbines corresponded to 388 MW. Enercon could extend its leading position, followed by Vestas and AN WIND. The 4th position was occupied by

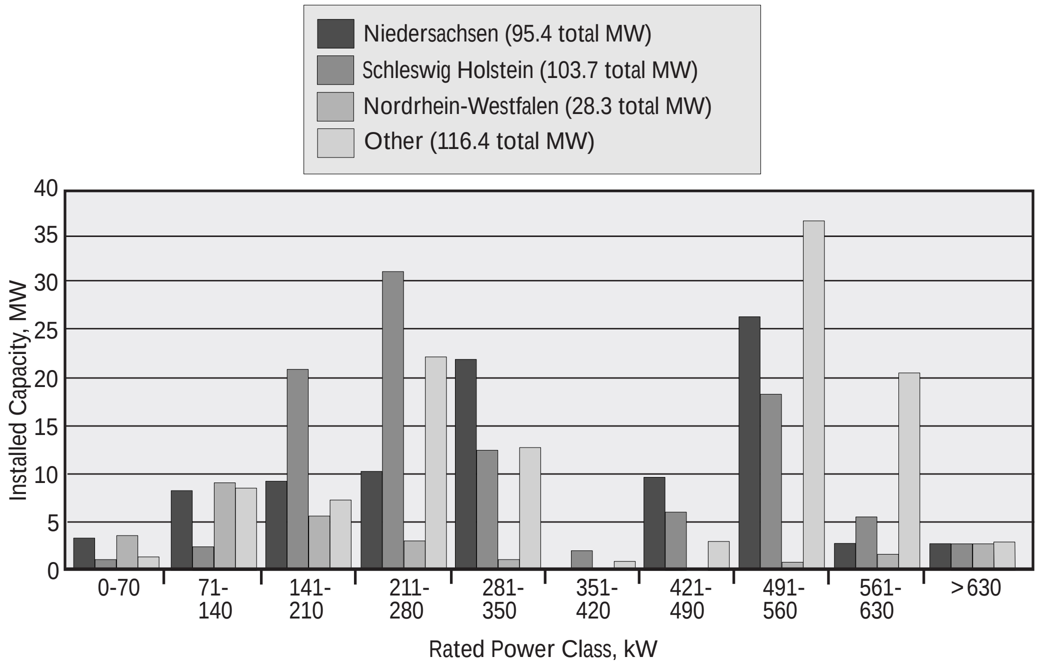

Figure 11.1 WMEP. Regional distribution of rated capacity for different rated power classes by December 31, 1996.

NEGMICON followed by Nordex. No. 6 and 7 are Tacke and Jacobs Energy.

11.3.2 New Products and Technical Developments

The German company Enercon developed an advanced smaller size turbine, the E 30 (200 kW, gearless) especially for export. The demand for the new MW-class turbines has increased considerably. In 1997, 111 WECS corresponding to a rated power of 137 MW, with a rated power of more than 750 kW, were sold.

11.3.3 Business Developments

The number of direct and indirect employees in the German wind power industry is at present around 10,000. The total commerce connected with WECS in Germany in the year 1997 amounts to 1.3 billion DEM. In addition, service teams had to be set up. On the average, one serviceman is required for an installed capacity of 20 MW. These jobs are needed for the lifetime of the turbines. Good service teams are most important in order to maintain the excellent availabilities averaging 98.5 % obtained in Germany.

11.4. MARKET DEVELOPMENT

The rated power of the installed turbines has increased significantly over the years. In 1989 and 1990, the market offered WECS with a maximum power of 250 kW, which was soon followed by turbines producing 300 kW. Nevertheless, the majority of plants still had a rated nominal power of 100 kW or even less. The typical operator was assumed to be a farmer who produced the electricity for the needs of his own farm and fed the surplus electricity into the grid. This situation has rapidly changed owing to the technical and economical development of WECS.

Table 11.4 Ownership of WECs of 250-MW Wind Program by January 1998.

OWNERSHIP	PROJECTS	WECS	RATED POWER (MW)	RATED POWER (kW)
Private individuals	595	677	122.4	181
Farmers	252	259	35.7	138
Trade and industry	233	451	157.0	349
Communities	51	57	7.4	130
Electricity companies	31	66	20.1	304

Most of the WECS erected in 1996 and 1997 have a rated power of 500 kW and more. In 1997 the introduction of the 1,500 kW class started very successfully.

Market constraints, especially in the German coastal areas, include complaints that wind turbine installations are destroying the landscape and disturbing wildlife and birds. Neighbors of WECS complain of noise and shadow effects. Germany has a high population density and is short of good wind sites, where different users are often competing. Owing to the necessity of noise emission reduction, a distance of about at least 500 m to the next resident is recommended for large-scale WECS. Although the corresponding land around a WECS can still be used as farmland, there are a lot of complaints. Over the past few years, it has become more and more difficult to get a construction permit for WECS.

11.5. ECONOMICS

The rapid market development the late eighties to the nineties was driven by the favorable financing conditions in the period. The “250 MW Wind“ Program, at that time the “100 MW-Wind“ Program, of BMBF led the way.

The “Electricity feed law“ (EFL) became effective by January 1, 1991. Since then, the utilities have been obliged to pay the same 90% of the average tariffs per kWh that private consumers have to pay, with taxes of 15% excluded. In 1997 this amounts to 0.1715 DEM / kWh and 0.1679 DEM / kWh in 1998. EFL and “250 MW Wind“ Program are cumulative.

In late 1997 the German Bundestag approved a modification of the EFL to reform the energy law, but the necessary approval of the German Bundesrat (deputizing the Federal States) was not given. The next steps were the action of the mediation committee between the two houses of the parliament to reconsider the energy law. Finally the law will come into force in early 1998. The changes in the EFL do not affect this refunding, but specify the financial charges of the different utilities of the German grid and set a date of a reconsideration of these specifications by the Bundestag (1999).

The discussion of possible changes of the EFL 1997 caused considerable concern in the German Wind Power Market. But the final result, an additional 534 MW of wind power in Germany, was even better than in 1995.

In addition to the reimbursement according to the EFL, a wind turbine operator might get soft loans. The Deutsche Ausgleichsbank offers soft loans for WECS with an interest rate one or two percent lower than on the capital market. Some states in Germany have terminated

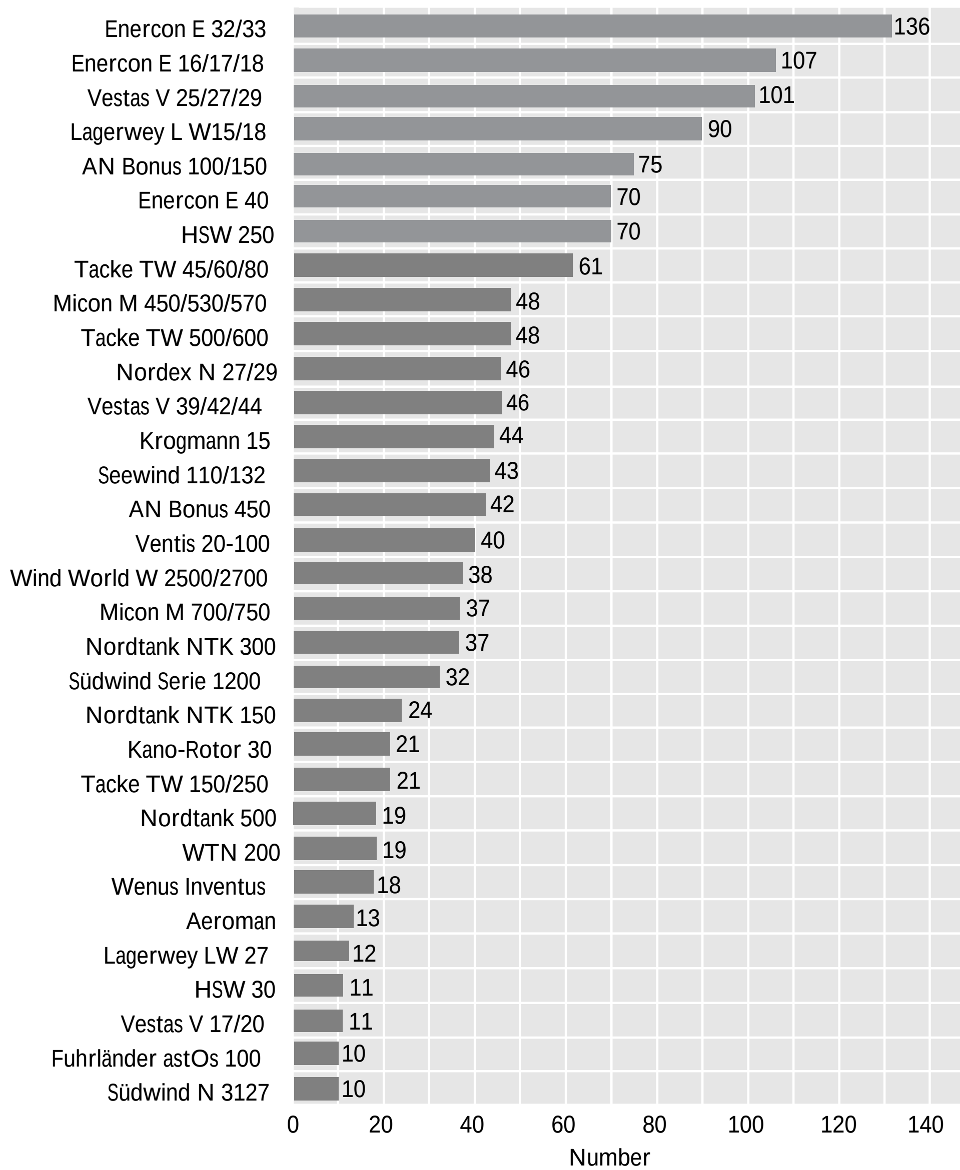

Figure 11.2 WMEP: WECs types by December 31, 1997.

their investment funding programs or switched over to soft loans, while some other States, especially in the German inland, still conduct programs with direct funding.

Over the last seven years a market for wind turbines has been established in Germany which does not depend on direct funding. Nevertheless, this market depends on: the conditions for reimbursement regulated in the EFL; the development of key turn prices of WECS; and the interest rate for loans and mortgages. A high value for interest rates for mortgages with a pay back time of 10 years was reached at about 10% by April 1991. This was followed by a fluctuating decrease to less than 7% today. Assuming a pay back

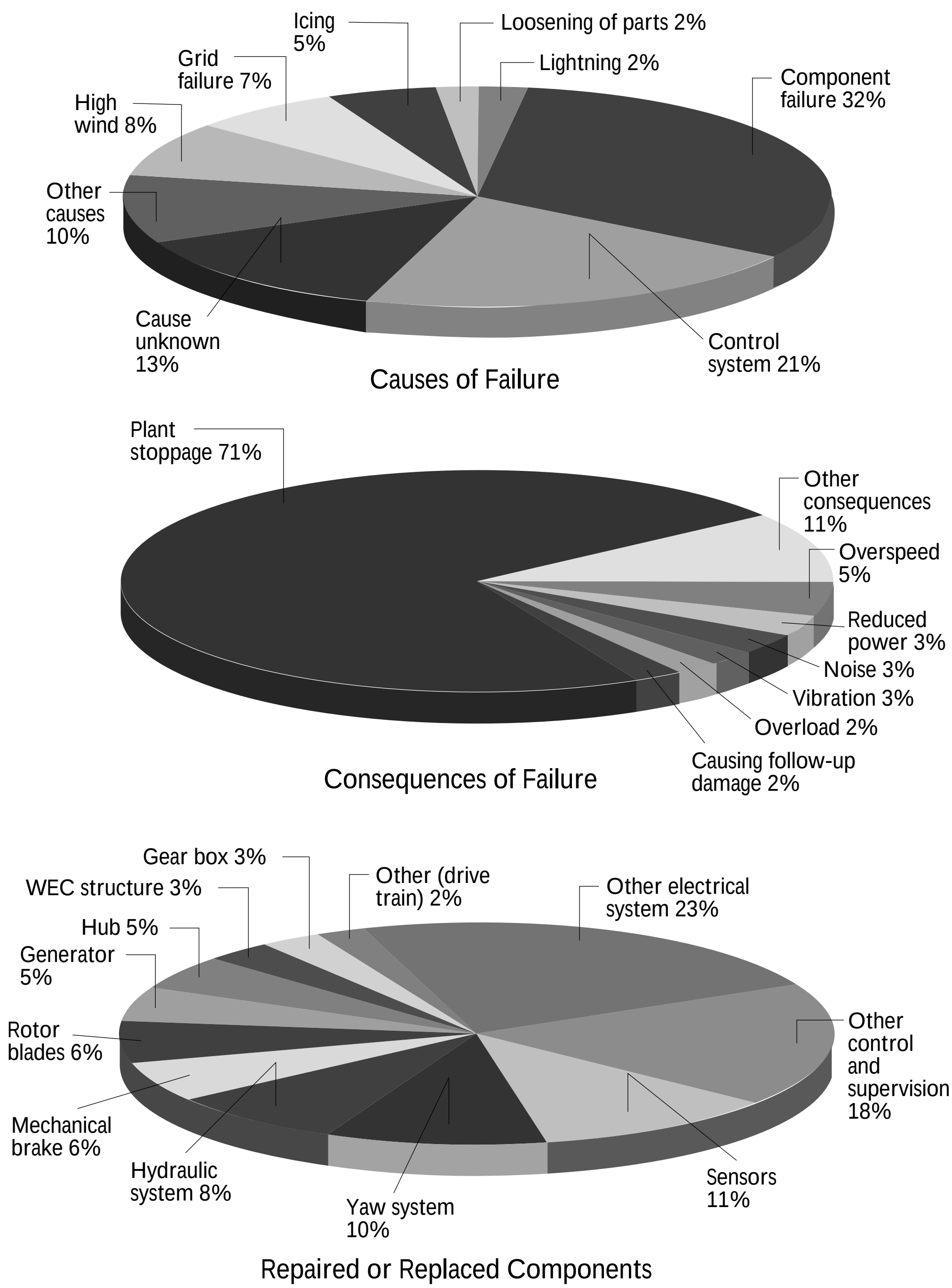

Figure 11.3 WMEP. Examples of failure statistics in 1997 (preliminary).

OTHER ELECTRICAL	162
Inverter	20
Fuses	49
Contactors/Switches	36
Cables	29
Others	28
OTHER CONTROL AND SUPERVISION	126
Microprocessor	84
Relays	21
Wiring/Contacts	11
Others	10
SENSORS	78
Wind Speed & Wind Direction	37
Vibration	4
Temperature	5
Oil Pressure	6
Electric Power	1
RPM	17
Others	8
HYDRAULIC SYSTEM	53
Hydraulic Pump	7
Pump drive	1
Valves	6
Hydraulic Pipes	11
Others	28
ROTOR BLADES	45
Blade Joints	10
Blade Body	9
Tip Brakes	12
Others	14
YAW SYSTEM	69
Azimuth Bearing	5
Motor	37
Gear	3
Others	24
MECHANICAL BRAKE	40
Brake Dick	4
Brake Lining	19
Brake Shoe	5
Others	8
GENERATOR	35
Winding	4
Collector/Brushes	11
Bearings	3
Others	17
HUB	37
Hub Body	2
Blade Adjustment	29
Blade Bearings	3
Others	3
WEC STRUCTURE	19
Foundation	—
Tower/Bolts	4
Nacelle Structure	4
Nacelle Cover	5
Others	6
GEAR BOX	19
Bearings	5
Gearwheels	1
Gear Shafts	1
Sealings	4
Others	8
OTHER (DRIVE TRAIN)	11
Rotor Bearings	4
Shafts	1
Couplings	4
Others	2

Figure 11.3 WMEP. Examples of failure statistics in 1997 (preliminary) continued.

time or a depreciation time of 10 years, it can be calculated by established methods that a decrease of three percent in interest corresponds to a price decrease of 25%.

The revenue from WECS is mainly determined by the electricity production, which can be expressed by hours of operation per year at nominal power. Under German meteorological and on financial conditions, it is more or less generally accepted that for a WECS erected in 1997 the revenue will be higher than the expenses when 2200 hours at nominal power are obtained. At good sites close to the German or to the Baltic Sea, where the mean wind velocity at a height of 10 m is between 5.5 and 6 m / s, the majority of WECS have lower production costs than revenue per kWh according to the EFL. The inland situation, where typical wind velocities of 4 m / s dominate, might be different. The broad distribution of full load hours is remarkably broad for the three site categories: coast, low mountains, and inland. This indicates that besides the general wind regime, other factors like the size and type of the turbine and the local wind conditions may influence the full load hours considerably.

Financing of WECS is often managed with low equity. Even on inland sites, the projects are sometimes financed completely by loans. Here, the revenue from the WECS is needed in the first ten years to pay for the capital costs, the insurance, and O&M. But the investor may nevertheless make some profit. A depreciation time for WECS of ten years was possible until mid 1997. From July 1st the depreciation time is 12 years. With a linear depreciation an investor can reduce his taxable income by about ten percent of the turnkey costs per year. This corresponds to approximately DEM 100,000 per annum. With an assumed tax rate of thirty percent, the taxes to be paid by the investor will be reduced by about DEM 30,000 per annum. Under the circumstances considered, almost no corporation taxes will have to be paid in the first ten years. Reducing the taxable income is one of the driving forces of the German WECS market. On average, every investor is reducing his annual taxes considerably.

11.6. GOVERNMENT-SPONSORED PROGRAMS

11.6.1 Funding 1997

The BMBF 1997 funding levels of wind power were (1996 in brackets):

R &D	DEM	5.5 (5.5) million
“250 MW Wind“	DEM	35.3 (44.3) million
ELDORADO	DEM	6.3 (6.8) million
Total	DEM	47.1 (56.6) million

In addition, the Federal Ministry of Economics supports renewable energies within special guidelines for the period 1995-1998. The guidelines include the investment grants for wind turbines of rated power from 450 kW to 2 MW at sites with average wind speeds up to 4.5 m / s at 10 m height above ground. About 10 projects per year with a total of around DEM 1 million are being realized.

11.6.2 R&D / WMEP

Recent R&D-Projects by BMBF are shown in Table 11.6. These include the development and test of three large-scale WECS: The E-66 by Enercon, the 1.2 MW (two bladed) the A-1200 by Autoflug, and the TW 1300 by Tacke. The Scientific Measurement and Evaluation Program, Phase III (WMEP) involves a DEM 13,683 million contract for the period of July 1996 to June 2000.

11.6.3 “250-MW Wind“ Program

The goal of the “250-MW Wind“ Program is to carry out a broad test of the application of wind energy on an industrial scale, which extends over several years. As an incentive for their participation in the “250-MW Wind“ Program, operators of the wind turbine / wind farm receive grants for the successful operation of their installations.

The current subsidy for operators in the "250 MW Wind" Program is either DEM 0.06 or DEM 0.08 per kWh, depending on whether the energy is fed into the grid or is being used by the owner of the WECS. The latter applies for instance to a farm, a factory or a private household, and also to a utility as a WECS owner. The grants are limited to a maximum of 25 % of the total investment costs. In certain cases (private individuals, farmers) a subsidy of the investment, limited to DEM 90,000, is possible.

The interest in support of the "250 MW Wind" Program was high. Until the closing date for proposals (December 31, 1995) more than 6,000 proposals were registered. This corresponded to a total rated power of more than 3,500 MW. During the development of the program a total of 1,223 proposals were approved, corresponding to 1,573 WECS and 384.5 MW. The last approvals were for some projects with the new MW-size turbines erected in 1997. The program will end around the year 2008 after 10 years of WMEP participation of the MW-size turbines.

It is expected that the total support will exceed DEM 350 million. The costs of the measuring program are not included in this sum and could reach additional DEM 60-70 million for the period 1990 to around 2007.

11.6.4 "ELDORADO Wind" Program

BMBF's interest also includes the application of wind energy in overseas countries. According to a study by the World Bank, almost 50 % of the inhabitants in developing and threshold countries do not have access to central energy supplies (electricity, oil, gas etc.). They could be assisted by decentralized concepts, and renewable energies are considered to be an option for decentralized energy supply. Therefore, BMBF launched the "ELDRADO Wind" Program in 1991, which is now being jointly carried out with 10 partner countries. The aim of BMBF is to encourage a large number of users in southern climatic zones to construct and operate WECS in cooperation with German partners. By December 31, 1997, 29 projects were approved by BMBF, most of them with installations in operation. The total rated power is 30 MW (see Table 11.7).

Table 11. 5 Market Shares 1997 in Germany.

MANUFACTURER	RATED POWER		WECS	
	%	MW	%	NUMBER
ENERCON	37.4	199.7	40.6	345
VESTAS	13.4	71.6	12.3	104
ANWIND	12.6	67.3	13.4	114
NEG MICON	12.2	65.1	11.0	94
NORDEX	11.7	62.5	9.4	80
TACKE	5.0	26.7	5.1	43
JACOBS ENERGIE	1.6	8.5	1.8	15
OTHERS	6.1	32.6	6.4	54
TOTAL	100.0	534.0	100.0	849

Table 11.6 Wind Energy R&D Projects, 1997 and the WMEP Phase III.

SUBJECT	PARTICIPANTS	PERIOD	COSTS (DEM)	BMBF (%)
Wind powered desalination plant, Rügen	Rügenwasser GmbH	06.93-05.97	3,891.5	70
Partial supply of the hydro pumped storage plant at Geesthacht with wind and PV	Hamburger Electricitätswerke	02.89-05.96	10,034.6	40
Evaluation of energy economics of Aeolus II	Preussen Elektra Windkraft NDS	10.91-12.96	0,577.4	50.0
Processing of wind measurement data up to 150 m for a planned archive of wind data	Deutscher Wetterdienst	04.92-01.98	0,607.0	100.0
Construction and installation of a quiet and economic 1.5 MW WEC	Enercon	01.93-04.96	7,745.0	14.20
Special wind data and programs for complex terrain	Deutscher Wetterdienst	07.93-06.97	1,641.9	100.0
Phase III of 250 MW wind measurement and evaluation program WMEP	ISET	07.9-06.00	13,683.5	100.0
Early recognition of turbine failure	ISET	01.94-12.96	1,431.8	50.0
Installation and measurement program Ventis V 12	Deutsche Windenergie Institut DEWI	04.94-03.99	1,085.0	36.9
Development and construction TW 1500 with 1 MW rated power	Tacke-Windtechnik	06.94-09.96	5,813.5	25.0
Detailed Investigation WT Flicker	Windtest Kaiser-Wilhelm-Koog	01.95-12.96	0,416.8	50.0
Fatigue Loads WECs	VDMA	07.95-6.97	0,443.6	50.0
MW WECs inland	RWE	06.95-12.97	4,893.6	20.43
Control LS WECs	ISET	07.95-06.98	1,192.9	40
Noise reduction WEGs	Fördergesellschaft Windenergie	12.95-11.96	0,283.2	100.0
Active stall rotor blade	Abeking & Rasmussen	08.96-07.98	2,505.1	50
Lightning protection WECs	Fördergesellschaft Windenergie	10.96-09.99	0,600	50

Table 11.7 Projects of the ELDORADO Wind Program, status December 1997.

COUNTRY	SITE	NO.	TECHNOLOGY	APPLICATION	TOTAL RATED POWER (kW)
ARGENTINA	Santa Cruz	10	Ventis 20-100	Wind Farm	1,000
	Bariloche	3	AN-Bonus 450	Wind Farm	1,350
	Patagonia	2	TW-600	Single Turbines	1,200
	Buratovich	2	AN-Bonus	Single Turbines	1,200
BRAZIL	Minas Gerais	4	Tacke TW 250	Wind Farm	1,000
	Fortaleza	4	Tacke TW 300	Wind Farm	1,200
	Rio Grande do Sul	5	Ventis 20-100	Wind Farm	500
CHINA	Zhurihe	4	HSW 250	Wind Farm	1,000
	Dalian	4	HSW 250	Wind Farm	1,000
	Luoyang	10	HSW 250	Wind Farm (4,6)	2,500
	Qinghai	7	AN 150/30	Wind Farm	1,050
	Xinjiang	2	Tacke 600	Wind Farm	1,200
	Xinjiang	3	AN-Bonus 450	Wind Farm	1,350
	Hainan	5	Jacobs	Wind/Diesel	165
	Inner Mongolia	10	Wenus	Wind/Diesel	50
	Luoyang	3	HSW 250	Wind Farm	750
	Urumqi	3	Jacobs	Wind Farm	1,500
	Inner Mongolia	10	Wenus	Wind Farm	50
EGYPT	Hurgada	10	Ventis 20-100	Wind Farm	1,000
JORDAN	Hofa/Juhfiyya	5	Vestas V27/225	Wind Farm	1,125
LATAVIA	Ainazai	4	Tacke TW-600	Wind Farm	1,200
POLAND	Gdansk	2	Tacke 600	Wind Farm	1,200
	Plock	5	Seewind	Wind Farm	1,660
RUSSIA	Rostov/Don	10	HSW30	Wind Farm	300
	Wolgograd 1	1	Südwind N1237	Single Turbine	37
	Wolgograd 2	2	Südwind N1237	Single Turbine	74
WHITE	Minsk	4	Südwind	Wind Farm	1,080
	Minsk	2	Jacobs 500 kW	Single Turbines	1,000
UKRAINE	Donezk	5	Südwind	Wind Farm	1,350
TOTAL		141			30,021